D. E. Paulson
Nov, 1901.

ELECTRICITY

AND

THE ELECTRIC TELEGRAPH

TOGETHER WITH THE

CHEMISTRY OF THE STARS.

LONDON:
PRINTED BY SPOTTISWOODE AND CO.
NEW-STREET SQUARE.

ELECTRICITY

AND

THE ELECTRIC TELEGRAPH

TOGETHER WITH THE

CHEMISTRY OF THE STARS

AN ARGUMENT TOUCHING THE STARS AND THEIR INHABITANTS.

BY

GEORGE WILSON, M.D. F.R.S.E.

REGIUS PROFESSOR OF TECHNOLOGY, UNIVERSITY OF EDINBURGH, AND
DIRECTOR OF THE INDUSTRIAL MUSEUM OF SCOTLAND.

New Edition, revised,

WITH THE ADDITION OF

A DESCRIPTION OF THE ATLANTIC CABLE.

LONDON
LONGMAN, BROWN, GREEN, LONGMANS, & ROBERTS.
1859

PREFACE.

Since the previous issues of this Work were published, the Electric Telegraph has been extended, one may say, in nearly every direction; and the Channels separating Great Britain from the adjacent countries have been crossed at so many points, that in one important respect it has ceased to be an Island. But no alteration has been made in the principle of the Telegraph, whether as employed on land or under sea; and it has not accordingly seemed necessary to report at length the multiplication of submarine cables or the increase of electrically-dropped time-balls. To the multiplication of such, there is literally no limit; but the aim of the First Treatise of this Work would be defeated, were it to enter into details regarding these matters: its object is simply to explain the great physical facts on which the Electric Telegraph is based, and the more important mechanical and other devices by means of which it has been realised.

The Second Treatise was looked upon, in its first form of publication, by most who read it, as enforcing, by somewhat far-fetched arguments, a questionable conclusion. I have welcomed accordingly, with much satisfaction, the appear-

ance of the eloquent Essay, treating "*Of the Plurality of Worlds*," which has very recently been made public. It should rather have been entitled, "*Of the Non-Plurality of Worlds;*" for its great object is to enforce the conclusion urged by me in "*The Chemistry of the Stars*," which, in its briefest statement, is thus expressed: "The unequivocal testimony, then, of physical science, as it seems to us, is against the doctrine that life, as it appears on the stars, must be terrestrial in its nature, though we are far from wishing to affirm that planets, closely resembling the earth, may not occur in Space. It is enough for our argument to show, that there are myriads of stars which, for the reasons already given, are altogether non-terrestrial in their characters."—*Chemistry of the Stars*, p. 46.

The Author of "*The Plurality of Worlds*" is reputed to be one of the most accomplished men of science who adorn the English Universities, and he certainly is a man of great learning, whose treatment of his subject is marked by profound acquaintance with science, by rare literary skill, and by a spirit of reverence as rare, and as worthy of notice, as the science, the logic, or the poetry of his book.

He looks at his subject from an astronomical and geological, rather than from the chemical point of view which I have chosen. His work embraces a much wider field of discussion than my small Treatise does, and many of his conclusions differ from mine; but our chief aim is identical, namely, to claim for our earth uniqueness as an abode of living creatures, or at least to show that the probabilities are all against there being

many (the Author of "*The Plurality of Worlds*" would say against there being *any*) worlds like our globe in the Heavens.

I may now, therefore, ask from the reader of "*The Chemistry of the Stars*" a more careful perusal of an earlier version than "*The Plurality of Worlds*" contains, of the rather unpopular doctrine that the Earth has few or no Sister-Planets in Space.

GEORGE WILSON.

Edinburgh,
April 13th, 1854.

A Third Edition of this work having been demanded, the general text has been revised, and a considerable addition made, so as to include a description of the Atlantic Cable.

G. W.

Edinburgh,
November 20th, 1858.

ELECTRICITY

AND

THE ELECTRIC TELEGRAPH.

Our readers are all familiar with that beautiful production of Oriental romance, the tale of Aladdin and the Wonderful Lamp. He needed but to rub it to summon an almost omnipotent Genie, who fulfilled his wildest desires; and whosoever rubbed the Lamp had its Genie equally under his control. A deeper truth than its author probably intended, or than most of his readers have discovered, is shadowed forth in Aladdin's story. Some six hundred years before the birth of our Saviour, the keen-sighted, inquisitive Greeks had unconsciously realised the dream of the eastern legend. It was not by rubbing a lamp (although a lamp or any other piece of metal would have done quite well), but by rubbing a piece of amber, that they evoked an Invisible, and, as they believed, Living agent, which in our hands has done far more wonderful things than the genie of Aladdin's Lamp did, or could have done, for its possessors. The Orientals would have named this agent *The Genie of the Amber;* and such is the exact signification of the term we employ at the present day; for the word *electricity*, derived from the Greek name of amber, ἤλεκτρον (electron) denotes, when applied to it as a branch of knowledge, the Amber Science, and when applied to the agent of which it treats, the Amber Force or Amber Power.

It was known to mankind, however, many thousand years

before it received a name, or was developed by rubbing amber; and if we are to consider him the founder of electrical science who first observed an electrical phenomenon, then the honour must be assigned to Adam, who earliest, doubtless, of men witnessed a thunder-storm, and might have named the agency which produced it the Lightning Force.

There were other natural electrical phenomena, also, less striking than the thunder-storm, but still sufficiently remarkable to awake and occupy the attention of mankind, during the ages that intervened between the occurrence of the first thunder-storm that had a human eye-witness and these days of the Electric Telegraph. The spectacle of such phenomena has in some cases been recorded, but more frequently no record was made. Thus the ancient Greek and Roman naturalists and physicians, such as Aristotle, Pliny, and Galen, knew that there occurred, on the Mediterranean shores, a flat fish like a boy's kite, or a skate with all its angles rounded, called a *Torpedo*, which had the power of thrilling and temporarily benumbing the fisherman who trod upon it with his naked feet, as it lay half hidden in the sand. The dwellers on the banks of the Orinoko have, from time immemorial, had similar but even more vivid experiences of the power of the Gymnotus, or Electrical Eel, which abounds in the tributaries of that great river, to cramp the limbs of the incautious swimmer in these streams. In the Nile another electrical fish, the Silurus, has been familiar from ancient times, and its modern Arabic name, *Raa'ád*, signifying the Trembler, or Causer of Trembling, is probably the translation or reflection of some older term of similar meaning, older perhaps than the Pyramids.

Very recently, also, the zealous and intelligent missionaries of the United Presbyterian Church of Scotland, resident on the Western Coast of Africa, near the Delta of the Niger, have made Europe familiar with a novel electrical fish, allied to that in the Nile, and called the *Malapterurus*. Living specimens of this creature have been sent to Edinburgh and to Berlin, ac-

companied by the interesting statement that from time immemorial they have been employed by the African women to *strengthen* their young children, who are plunged into tanks or basins of water containing the living fish. Its shock is believed to profit the child, and to impregnate the water with healing virtues. A similar therapeutic application of the living torpedo was familiar to the Greeks and Romans, and still prevails among the Abyssinians; and the Negro slaves of South America, in imitation perhaps of a practice of the aboriginal Indians, welcome, when suffering from rheumatism, shocks from the formidable Gymnotus. There can be no question that the earliest shock-machine was an electrical fish, and that two thousand years before our physicians employed electro-magnetic coils to cure paralysis, electricity must have been simultaneously recognised and applied in opposite quarters of the globe—by the Mediterranean sailor, the North American Indian, the dweller by the Nile, and the Western African, as a benumbing, convulsing Torpedo, Gymnotus, or Electric Fish-force.

Electrical meteors, likewise, including the Aurora Borealis, must have been familiar to the men of all countries and ages. The Roman historians, such as Livy and Cæsar, tell how the spearheads of a whole legion under march were sometimes seen in dark fogs to be each tipped with flame; and the ancient sailors of the Mediterranean worshipped, as Castor and Pollux, the similar stars of fire which were often seen by them on the mastheads of their vessels. They are equally worshipped by the modern Italian mariners, who name them the fires of St. Elmo. Longfellow, in his *Golden Legend*, makes a Mediterranean sailor say:—

> "Last night I saw Saint Elmo's stars,
> With their glimmering lanterns all at play,
> On the tops of the masts, and the tips of the spars,
> And I knew we should have foul weather to-day."

In the Monkish Chronicles of the Middle Ages are descrip-

tions of individuals, who at certain periods appeared, when lying in bed in darkness, to be floating or swimming in waves of fire. These descriptions are greatly exaggerated, as was natural in a wonder-loving, superstitious, credulous epoch; but they referred to a truth sufficiently remarkable, even when stripped of all exaggeration. The bodies of living men and of certain of the lower animals may frequently, by rubbing them, be made to evolve sparks and flashes, so that, for the time, they are literally living electrical machines. The incidental friction attending the pulling off of a tight-fitting stocking, or other article of dress worn next the skin, has often unexpectedly developed electricity, to the surprise and terror of the party who was at once the electrifier and the electrified. The mediæval chroniclers, indeed, may well be excused if their pictures of such startling occurrences are somewhat overdrawn.

The main condition needed for such electrical developments on the surface of the body appears to be great dryness of the skin; and hence they are seen best in frosty weather, when the amount of water-vapour in the atmosphere is at a minimum, and in the persons of those who, from natural habit of body, long residence in tropical climates, or other causes, have dry, harsh, unglistening cuticles, and who perspire little. In such, electricity may at any time be developed in cold weather, by placing them on an insulating support, such as a block of gutta percha, a sheet of Indian rubber, a stool mounted on glass legs, or a board laid upon glass bottles, and rubbing the body and limbs with dry silk or flannel. Even without the formal insulating arrangement, electricity will be procured, provided damp be avoided.

These conditions are so readily realised in the colder seasons of the year in northern latitudes, that they must have been more or less familiar to mankind from the earliest periods. A recent case is on record as occurring in the person of an American lady, in whom, at certain periods, the mere friction of her dress was sufficient to develope electricity, so that when she

approached her hand to a door-handle, a bell-pull, a candlestick, or any other metallic article, a spark passed before she touched it. To her it was only a matter of temporary annoyance, and to those about her of amusement or interest. In the middle ages she would probably have been held to be possessed of an evil spirit, tormenting her before her time.

Within the last two years, however, this case has lost all its singularity. From observations made by Professors Loomis and St. John, in the cities of New York and Cleveland, it appears that in winter when the temperature of the outer atmosphere is below the freezing point, and that within the houses, as maintained by stoves, is about 70°, so that the air of the apartments is both warm and dry, almost anyone may render himself electrical, by walking, or rather skipping or shuffling, in dry slippers along the carpeted floor. The scientific interest of these observations lies in the fact, that the main source of the electricity thus liberated, has been shown to be, not the friction of the dress against the person (which, however, is a long recognised and ready source of electricity), but the friction of the shoes against the woollen carpet. In proof of this, it appears that no matter what dress is worn, provided the shoes or slippers are dry, and the floor carpeted, a few skips or shuffles are sufficient to enable persons of either sex to dispense with lucifer matches, and to light the gas by a spark from the knuckle or finger. Combing the hair in such warm and dry apartments makes it, if not too much oiled, crackle and sparkle in the dark, so as to light up the face with a strange gleam.

That heat, dryness, and friction are the only conditions requisite to produce such electrical phenomena is strikingly demonstrated by Dr. Livingstone's experience in the great Kalahari desert of Africa, where ice and stoves are equally unknown. "Occasionally," he tells us, "during the very dry seasons which succeed our winter and precede our rains, a hot wind

blows over the Desert from north to south. . . . This wind is in such an electric state, that a bunch of ostrich-feathers, held a few seconds against it, becomes as strongly charged as if attached to a powerful electrical machine, and clasps the advancing hand with a sharp crackling sound.

"When this hot wind is blowing, and even at other times, the peculiarly strong electrical state of the atmosphere causes the movement of a native in his kaross to produce therein a stream of small sparks. The first time I noticed this appearance was when a chief was travelling with me in my waggon. Seeing part of the fur of his mantle, which was exposed to slight friction by the movement of the waggon, assume quite a luminous appearance, I rubbed it smartly with the hand, and found it readily give out bright sparks, accompanied with distinct cracks. 'Don't you see this?' said I. 'The white man did not show us this,' he replied; 'we had it long before white men came into the country, we and our forefathers of old.' . . . . 'Otto von Guericke is said by Baron Humboldt to have been the first that ever observed this effect in Europe, but the phenomenon had been familiar to the Bechuanas for ages." (*Travels in South Africa*, chap. vi.)

The most electrical (superficially) of the lower animals is the cat, which pays for its fastidious cleanliness, its careful dressing of its fur, its dislike of damp, and love for basking in the sun or before the fire, by a greater susceptibility to electrical excitement than most other creatures. There are few cats in good condition which, if coaxed to sit on a dry stool (especially one with glass legs), may not be rendered electrical in frosty weather by stroking them. It is proverbial that they hate to be stroked the *wrong way*, or from the tail to the head, and one, perhaps the chief, cause of the dislike of these sensitive and luxurious creatures to the reversed stroking is the greater amount of electrical excitement which it occasions. The traditional connexion of cats with witches and evil spirits, which figures so largely in the German legends, is probably in part

connected with the observation of the mysterious sparks which, at times, they flashed out when stroked, and the impatience of caresses which attended those fiery manifestations. Many a poor cat doubtless paid with his life for his unwilling and unwelcome feats as an electrician; and when, at a later period, the practical Dutch philosophers recognised that in the nature of the animal's fur lay the secret of its electrical susceptibility, they killed hosts of cats for their skins, and gave the latter the first place among the exciters of electricity. If the humane dream should prove true, in which Goldsmith indulges in the "Citizen of the World," that the torturers of animals on this earth will, after death, run the gauntlet in worlds each of which is occupied by a single class of the animals they have wronged, then the electricians may anticipate, with peculiar dread, their treatment from the spirits in the cat-world, and, next to them, from those in the heaven of the frogs. A frog's body is the most sensitive of all indices of electrical action; and many a harmless croaker has been a reluctant and uncommemorated martyr in the cause of science. But this is a digression.

Besides the electrical phenomena we have noticed as certain to have been matters of observation, more or less widely, for ages, we must add, as closely related to them, and to the special subject of our paper, the discovery of the natural magnet. This mineral, one of the oxides of iron, to which our English ancestors gave the expressive name of Loadstone, *i. e.* leading or guiding-stone, in reference to its services to the mariner in conducting him across the pathless ocean, has been known to mankind from a period lost in a fabulous antiquity. The word magnet is of Greek origin; but the Chinese were acquainted with it centuries earlier than the Greeks, and constructed compass-needles, in which, unlike our compass-makers, they marked the south pole as the more important end of the needle.

The phenomena we have noticed constituted the entire stock of electrical knowledge possessed by mankind from the commencement of the historic era down to the beginning of the

17th century. These phenomena, however, were not known to proceed from a common source, or to be related as unlike effects flowing from a single cause. The amber-force was not suspected to be identical with the lightning-force; or both to be the same in essence with the thrilling power of the Torpedo, and the illuminating agency of the atmospheric meteors. Neither did anyone as yet know that electricity and magnetism are sister-forces as inseparably associated as the shadow is with the illuminating body throwing it; so that the one cannot be developed without developing the other. Nor, so far as history tells, did anyone improve upon the observation made first by Theophrastus, 600 years B.C., that rubbed amber attracts light bodies, and succeed in constructing a machine by means of which electricity could be produced artificially on a large scale. So far as we know, no one even attempted such a construction. It is only within the last 250 years, and chiefly within the last 50, that we have learned at the hands of men recently dead, or still living, the common source of the phenomena referred to as so long known to mankind, and have been taught how to produce and to regulate electricity at will. A few references will demonstrate this.

The entire annals of the ancient world do not supply the names of a dozen persons who can be styled electricians; and even these only observed or recorded isolated phenomena. The educated and uneducated portions of mankind stood nearly on the same level in reference to them. The Italian fishermen knew more concerning the powers of the Torpedo than Aristotle or Galen, who merely repeated what the fishermen told them; and the Roman legionaries were more familiar with the meteoric stars which occasionally tipped their javelins than Cæsar, or Livy, or Pliny, who chronicled their appearance.

No doubt, for men of genius like those we have named, a phenomenon had a much deeper significance than it had for unlettered fishermen or barbarian soldiers; but, after all, it taught the former, so far at least as they have instructed us,

little more than it did the latter; and the fisherman and soldier, as the more experienced observers, must be counted the best electricians of an epoch in which no electrician was more than an observer.

Electricity, as a science, may be considered as dating from the year 1600, when Dr. Gilbert, a native of Colchester, published, in London, a Latin treatise on the magnet. It discusses electricity as well as magnetism, explains certain of their fundamental laws, and announces certain conclusions in a truly sagacious and philosophical spirit. Curiously enough, this treatise, which we look back upon as far before its age, and destined to a lasting place among works on science, was selected by Lord Bacon as an example of inconclusive and vicious reasoning: so much more easy is it to give advice than to take it, or even to see that it has already been taken.

The disparagement of Gilbert's inquiry prevented it attracting the attention it otherwise might have received; so that more than half a century passed before electricity was taken from its cradle. In 1670, however, the famous burgomaster of Magdeburgh, Otto Guericke, who is memorable in scientific annals as the deviser of the first air-pump, made a new claim on the reverence of posterity by his construction of the first electrical machine. It was a globe of sulphur, made to whirl on a vertical axis, whilst it was rubbed by the hand. Otto Guericke cast the sulphur in a mould of glass; and it was afterwards discovered that the hollow glass sphere did better than the core of solid brimstone, to set free which the glass was broken; but, compared with the fragments of yellow amber which Theophrastus rubbed, the sulphur globe was a wonderful electrical machine.

The centenary of Dr. Gilbert's observations marked a retrogression in electrical science. The value of large machines was not appreciated, and the commencement of the 18th century was unhappily signalised by a return on the part of observers, headed by Hauksbee, an English experimentalist of

repute, to the glass tubes which were the electrical instruments in vogue before Otto Guericke's time.

Yet with these tubes good work was done; and by the year 1730 the great discovery had been made that all solid bodies may be divided into two classes,—viz., *electrics*, such as glass and amber, which, if held in the hand and rubbed, evolve electricity; and *non-electrics*, such as the metals, which, in the same circumstances, evolve none. This was the discovery of Stephen Gray, an Englishman; and about the same time Dufaye, in France, made the observation that there are two kinds, as he expressed it, of electricity, the one of which he named *vitreous*, the other *resinous*.

In 1745 the Germans returned to the use of large machines, like Otto Guericke's, but made of glass. An immense extension of electrical science followed this step. In truth, when we read the descriptions of the earliest machines, we cannot but wonder that so much was done with them. They recall the "three-man beetle" with which Falstaff ironically wished he might be filliped. Like it they were three-man machines. One person stood on the floor, holding in one hand a large glass tube, and rubbing it with a piece of silk held in the other. A second party stood near him, mounted on a glass-legged stool, and holding towards the rubbed tube one end of a metallic rod terminating at either extremity in a ball, whilst opposite its other end stood a third party on the floor, who received sparks from the ball nearest him, and experimented on the electricity accumulated on it.

After the replacement of this and other cumbrous and inefficient arrangements by revolving glass cylinders, spheres, and plates, the rate of progression, which before may be said to have been arithmetical, became geometrical. We can only, therefore, glance at the important dates after 1745. In 1746 Holland was a great seat of electrical inquiry; and a new and most valuable weapon of research was placed in the hands of all by the Dutch electricians who devised the Leyden jar. The

same year is memorable as that in which the great Italian Volta began his electrical studies; and the next year, 1747, saw Benjamin Franklin follow his example. In 1752 he showed the identity of lightning and electricity. In 1775, Walsh, Hunter, and Cavendish proved, by experiments on the living torpedo, dissections of its dead body, and imitations with machines of its benumbing powers, that it possessed a very powerful and peculiar electrical apparatus, which, during life, it could will into action when it pleased.

In 1777 Volta showed that an electric spark could be most conveniently applied to kindle gases; and within six years the application of the spark, in the way proposed, had led, in the hands of the English chemists, to the great discovery that water is not an element, but a compound of two very unlike gases.

The year 1780 is an *annus mirabilis* in Electrical Annals. In connexion with it the present writer has in previous editions repeated the famous story of Galvani and his wife, and their dealings, electrical and culinary, with the limbs of dead frogs. Some twenty versions of this tale are known on the continent; and as Alibert, the formal eulogist of Galvani, and Arago, the formal eulogist of Volta, have repeated it with little variation, it has been accepted as true in this country. It is certainly, however, a myth which wrongs alike Galvani and his accomplished wife, Lucia. The former had for years been investigating the source of muscular action in frogs and other animals: the latter was her husband's devoted and intelligent assistant in his researches. The celebrated frog was dismembered, not for culinary but for scientific purposes, and was awaiting Galvani's return in a part of his laboratory where an electrical machine was at work. Lucia Galvani, who was looking on, was startled by observing that whenever the machine gave out a spark the limbs of the frogs were convulsed, and struggled as if still parts of a living body. She called her husband, who mistook in part the nature of this singular phenomenon, and was long thought

to have mistaken it altogether; but his merits are better appreciated now, and his countryman Matteucci has in our own day vindicated the justice of many of Galvani's forgotten or despised views concerning the existence of electrical currents in the bodies of all animals. He is referred to here, however, solely because he has given its name to that development of electricity which is most to concern us in what follows. The word GALVANISM is as firmly rooted in our language, and as widely spread, as that of CALVINISM, which in sound, though not in sense, it so closely resembles.

The 19th century, which has far excelled all previous centuries in the success with which it has cultivated physical science, was not to commence without a remarkable electrical achievement. In 1800, Volta, who was Professor of Natural Philosophy, first at Como, afterwards at Pavia, devised the remarkable machine which has since deservedly borne his name, and is known as the Voltaic circle, pile, or battery. In the same year, its immense power to effect chemical decomposition was discovered, and by means of its agency even water was decomposed, and first in England. The hour had plainly come for a great advance in chemistry; and the man who should make it was forthcoming also. Davy commenced his electrical researches in 1800, and, besides much else, he had directly or indirectly given to the world twelve new metals before the end of 1807.

The whole civilised world was now astir with electrical excitement. Napoleon offered a prize for the greatest galvanic discovery; and hostile enactments were suspended, that the victorious English Davy might proceed to Paris to receive the prize for which all Europe had contended.

Throughout this period men's minds had been haunted by the conviction that some close, though veiled alliance subsisted between electricity and magnetism. It was given to Oersted, the Dane, to discover the clue to this, and to announce

the observation of the influence of an electrical current over the position of a compass-needle, which led in a wonderfully brief time to the invention of the Electric Telegraph. This was in 1819. In 1821 Seebeck of Berlin discovered that by the unequal heating of associated metals of unlike character electricity is developed. This thermo-electricity has supplied us with an exquisitely delicate thermometer—far surpassing all the ordinary measurers of the intensity of heat, and has likewise furnished the probable explanation of the magnetism of the earth. Our revolving globe, heated unequally by the sun, has, according to this view, currents of electricity determined in it, in directions corresponding more or less closely to its parallels of latitude; and, as a consequence of this, possesses north and south magnetic poles, which may be developed in an artificial globe similarly traversed by electrical currents.

About the same time, Ampère and Arago, in France, discovered the power of an electrical current to develope magnetism; which, along with Oersted's observations, laid the foundation of electro-magnetism, the science which stands in closest relation to the Electric Telegraph.

In 1821, also, Faraday, the greatest living electrician, began his original labours. In 1830, he demonstrated the practicability of evolving electricity from magnets, and was the chief founder of the branch of the science named Magneto-Electricity, which is fast rivalling galvanism in its applications to the useful arts.

From 1830, onwards, Faraday proceeded in his career of discovery; and to him, more than to any other single observer, we owe the demonstration of the essential identity in nature and power of all the so-called different kinds of electricity. He furnished the true explanation of its decomposing power over chemical compounds, which Sir Humphry Davy, with all his genius, had in several respects misinterpreted; and, besides much else, he discovered that as a loadstone renders magnetic

all the iron in its neighbourhood, so a current of electricity, proceeding from a battery along one wire, developes a momentary current along another and passive wire stretched near it. To this observation medical men, and their suffering patients, are indebted for the most efficacious methods of applying electricity to the cure of disease.

To this period belongs the date of greatest practical interest in reference to the telegraph. In 1837, the inexhaustibly ingenious Wheatstone, and Cooke, a man in whom the practicality of the English character showed itself in its fullest, freest development, took out their patent for an electric telegraph; and to them, as the earliest practical telegraphists, belongs the honour which attaches to that difficult step in all enterprises, *le premier pas*, but of which, in their case, it may be emphatically added, *qui coute.*

From 1837, onward to 1851, it may suffice to refer to Faraday, who has distanced all his electrical competitors. In 1845 he startled the scientific world by his announcement of the subjection of light to magnetic influence. From that period onwards to 1850, he has kept constantly adding to his remarkable observations on a *new magnetic condition of matter*; from which we have learned that the reproach we complacently cast upon our forefathers, for fancying that amber only was electrical, will be retorted on us by our descendants for thinking that iron only was magnetic. The proof of this may be said to have reached its climax when, in the autumn of 1850, Faraday showed that the very air is magnetic, and that soap-bells, or glass-bubbles, filled with its more important gas, oxygen, will move towards a powerful magnet, as a piece of iron does. Whilst we write, a paper is in the press, which will speedily appear, containing Faraday's latest magnetic discoveries.

From this account it will be seen, that men have learned more concerning electricity in the last half-century than they did in all the centuries together which preceded it: and that

though some nations have contributed more than others to its extension, no single people has monopolised its discoveries or applications. Knowledge is not a fixed sun in the heavens, revolving only on its own axis, but a planetary torch which passes from land to land, now blazing brightest on one shore, and then on another. The Greeks begin empirical electricity; the Romans continue it. The Chinese begin magnetism: the English Gilbert sketches the outline of magnetism and electricity as sciences: the German Otto Guericke makes the first electrical machine: the French Dufaye discovers the two electricities: the Dutch Muschenbröck devises the Leyden jar: the Italian Volta constructs the pile: the American Franklin shows the identity of lightning and electricity: the Danish Oersted discovers electro-magnetism. A single name has been selected in each nation, but each can boast of several. Germany, Italy, France, and England have produced the greatest number of famous electricians; and the science, as it now exists, is a monument to the genius and labour of a multitude of gifted men, belonging to different countries, races, and times.

We are now to look a little more particularly into the nature of electricity, and the mode of applying it in working a telegraph.

A difficulty, at first sight very formidable, attends all explanations of electrical phenomena. The question is asked, What is electricity? And to this no categorical answer can yet be returned. The question, however, may be set aside, as not requiring to be answered before the effects of electricity are considered. Of the nature of heat and of light, as well as of magnetism, we are in truth still quite ignorant: but we do not hesitate to discuss the changes which matter undergoes when illuminated, heated, or magnetised, without waiting till our theories of heat, light, and magnetism are perfect. We can do the same, therefore, with electricity, in explaining the telegraph, or any other electrical contrivance,—provided we adopt some provisional theory as to its nature, which shall

supply us with suitable terms for describing the phenomena, although it may be quite inadequate to account for them.

Two views, setting aside minor modifications, are entertained concerning the nature of electricity,—very analogous to those now held concerning the nature of heat, light, and magnetism. According to the one view, electricity is a state, condition, or power of matter; according to the other view, electricity is a peculiar substance, or form or kind of matter. The latter is the more easily apprehended hypothesis; and supplies the nomenclature almost universally adopted in describing electrical phenomena, even by those who prefer, as more probable, the opposite belief. Electricity, then, may be assumed to be a highly attenuated substance,—analogous to an elastic fluid, such as hydrogen gas, but infinitely lighter; in truth, not sensibly heavy at all. In bodies not exhibiting electrical phenomena this imponderable entity is supposed to exist in a latent or insensible condition, hidden as it were in their substance or pores. Bodies, on the other hand, which manifest electrical phenomena, have the imponderable fluid set free at their surfaces, in an active, sensible, or non-latent condition: so that it envelopes them, as a fog does a mountain-top; or flows over them, as smoke does over the mast of a ship; or flows through them, as a current of warm water streams through a mass of cold. Electricity, as thus defined, is as invisible as common air; but when its intensity is high, it is cognisable by all the senses. It addresses the eye by its spark or lightning-flash; the ear by its snap or thunder; the nostrils by a peculiar indescribable odour which it develops; the tongue by an equally peculiar taste which it occasions; and the organs of touch by its characteristic shock. The unknown something, condition, or kind of matter which is the cause of those and many other phenomena, is electricity. We shall, for the present, write of it as a kind of matter, *i. e.* as something over and above, or superadded, to the body, whatever that be,

which exhibits electrical phenomena; so that a telegraph-wire will be referred to, as conveying a current of substantial electricity, as a gas-pipe conveys gas, or a water-pipe water. Before, however, we can consider how this wonderful agent is made to convey intelligence, we require to notice certain relations of electricity which we proceed to discuss.

The phraseology of scientific treatises, in reference to electrical phenomena, is very apt to mislead and perplex those who consult them for information concerning special points. Such terms continually occur as, statical electricity, dynamical electricity, positive electricity, negative electricity, electricity of tension, electricity of quantity, friction electricity, voltaic electricity, animal electricity, magneto-electricity, thermo-electricity —till the distracted reader, who finds one electricity perplexing enough, loses count and heart, and closes the treatise in despair. But this formidable list of electricities, which might readily have been lengthened, fortunately admits of being reduced to *two kinds* of electricity, and *two modifications* of each kind. The kinds are *Positive* and *Negative* electricity. The modifications are electricity *of Tension*, and electricity *of Quantity*. Statical and dynamical refer respectively to free electricity, as either at rest or in motion; and the five other titles merely point to certain important sources of electricity,— which, however, is essentially the same, whatever be its source. The titles, positive and negative, apply to a much deeper and more fundamental peculiarity of electricity than the terms tension and quantity; but the latter are more important in reference to its practical applications; inasmuch as they are variable; whilst the twofold positive and negative relation of this agent is constant—and, so far as we at present know, inseparable from the very existence and manifestation of all electricity. We shall discuss this duplex character of electrical force presently; but it will be better appreciated after

the difference between electricity of tension and electricity of quantity has been shortly explained.

The phrases in question, which, philologically considered, are inaccurate and inelegant enough, are used to denote the difference which is found to exist between the quantity of electricity which any source of it, such as a voltaic battery, furnishes, and the intensity of the electricity so furnished. The distinction is one of the same kind as that which is familiarly recognised in the case of light and heat. In the phosphorescence of the sea, for example, which often spreads continuously over thousands of miles, we have an illustration of light very feeble in intensity, but enormous in quantity; a white-hot platinum wire, on the other hand, gives out a very small quantity of light, but that of high intensity; while the sun radiates light at a maximum, as regards both intensity and quantity. A similar variation exists in the case of electricity; but we have no electrical sun, *i.e.* no source, natural or artificial, of electricity alike great in quantity and in intensity.

We measure *the quantity* of electricity in many ways; but most conveniently by the amount of any chemical compound which it can decompose. A machine or battery, for example, which, when arranged so as to decompose water, evolves from it four cubic inches of oxygen and hydrogen in one minute, is furnishing twice the quantity of electricity supplied by an apparatus which evolves only two cubic inches of the gases in the same time. The *intensity* of electricity is less easily measured; but is well enough indicated by the ease with which it can travel through bad conductors; by its power to overcome energetic chemical affinity, such as that which binds together the elements of water; by the length of space across which it can pass through dry air (as in the case of the lightning flash striking a tree from a great distance); by the attractions and repulsions it produces in light bodies; and by the severity of the shock it occasions to living animals. Tried by those

tests, and by others, we find that the electricity of the friction-machine, of an insulated steam-boiler, or of a thunder-cloud, has extraordinary intensity—while its quantity is excessively small. We speak very much within bounds when we state, that the whole electricity of a destructive thunder-storm would not suffice for the electro-gilding of a single pin,—so insignificant is its amount. A small copper wire, dipped into an acid along with a wire of zinc, would evolve more electricity in a few seconds than the largest friction electrical machine, kept constantly revolving, would furnish in many weeks. No shock, on the other hand, would be occasioned by the electricity from the immersed wires; nor would it produce a spark or decompose water—so low is its intensity. A double-cell voltaic battery, again, produces electricity of such intensity that its shock would kill a large animal; and it can force its way along very bad conductors—at the same time its quantity is so enormous, that torrents of oxygen and hydrogen rise from the water it is made to decompose.

Out of the distinctions thus explained, have arisen the phrases, electricity of Tension, and electricity of Quantity. Interpreted literally, those terms have no meaning. We cannot recognise the existence of any electricity, unless it possess such intensity as to produce some effect cognisable by our senses; neither can any intensity be conceived as separated from a quantity of electricity which possesses that intensity. The terms in use are thus very awkward. In ordinary language we should use intense electricity for the one, and leave the other undefined, or only call it abundant electricity. But those questionable terms are now universally employed; and are rendered necessary by the circumstance already adverted to, that we have no artificial method of producing enormous quantities of electricity at a high intensity. As produced by us, therefore, it must always take a character from the preponderance of its intensity, or the preponderance of its quantity.

Tension is merely a synonyme for intensity, which originated in the hypothesis of electricity being an elastic fluid, which might be regarded as existing in a thunder-cloud, or on the conductor of a friction-machine in a state of condensation or compression, like high-pressure steam struggling to escape from a boiler, or air seeking to force its way out of the chamber of an air-gun. The word tension, we believe, has been preferred to intensity, simply on account of its brevity, and its convenience in forming a double noun with electricity. Electricity of intensity then, or tension-electricity, is electricity characterised by the greatness of its intensity—or whose intensity is greater than its quantity. Electricity of quantity, on the other hand, has its quantity greater than its intensity. The intensity diminishes as the quantity increases; but the ratio which the one bears to the other, differs through a very wide scale, so that a knowledge of the. degree of the one does not often enable us to predicate the amount of the other. Practically, we have no difficulty in reducing both to a minimum, or in exalting the one whilst we reduce the other; but we cannot at once greatly exalt both intensity and quantity. The discovery of a method of effecting this, will make a new era in the science, and admit of the most important applications to the useful arts. Meanwhile we may compare electricity of tension, as we have done already, to high-pressure steam issuing in small jets under great pressure; and electricity of quantity to the thousands of cubic feet of invisible vapour which arise softly every moment from the surface of the sea. Or the former may be likened to a brawling, gushing mountain brook, rushing with great force but little volume of water; and the latter to the slow rolling Amazon or Mississippi, silently moving onwards to the ocean. Or the first to a swift, sudden hailstorm or avalanche, and the second to the inexhaustible glacier, constantly melting, but as constantly increasing. Or the one to an instantaneous gust or white squall, passing off in

a moment, and the other to the unceasing trade wind, for ever sweeping gently over the bosom of the waters.

It depends upon the purpose to which electricity is to be applied, whether it should be chosen great in quantity, or great in intensity. If the chemist desires to analyse a gaseous mixture by detonation, he will use the friction-machine, to supply a momentary spark of great intensity. But the electro-plater, who has constantly to decompose a compound of gold or silver, employs the magneto-electric machine, or a small voltaic battery,—which furnishes great quantities of electricity of considerable intensity. The electric light requires both quantity and intensity to be very great. For the electric clock the intensity may be at a minimum, and the quantity need only be moderate. The electric telegraph demands great quantity, but the intensity need not be very high.

This much premised, we may now consider its application to the construction of the telegraph. An electric telegraph consists essentially of three things. First, a voltaic battery or other apparatus to evolve, when required, electricity. Secondly, an arrangement of metallic wires or other good conductors, to convey the electricity to the distant places with which telegraphic communication is to be carried on, and to bring it back to the machine from which it set off. Thirdly, the application of the electricity so conveyed, to produce at the distant station some striking phenomenon, which, according to a preconcerted arrangement, shall represent a letter of the alphabet, a numeral, a word, a sentence, a paragraph, or the like. A source or fountain of electricity; conductors to carry it; and a dial plate on which it shall cause an index to exhibit signals, are thus the essential elements of an electric telegraph.

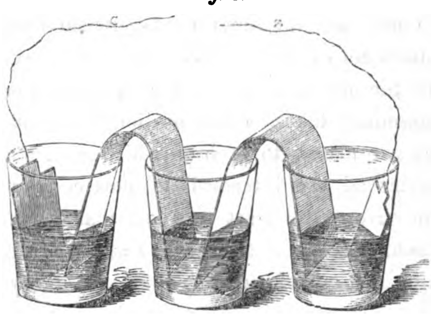
Our present object is to discuss chiefly what is electrical in the telegraph,—without much reference to the mechanical devices or subsidiary arrangements which it involves. Our first concern, then, is with the source of electricity; and, as our

space is limited, we shall confine ourselves to the voltaic battery, the apparatus chiefly in use along the telegraph lines. A voltaic battery, in its simplest form, consists of two dissimilar solids,—generally metals,—arranged side by side, without touching each other, in a liquid which dissolves only one of them. One of the solids is almost invariably a plate of zinc, rubbed over with quicksilver, or, as it is called, amalgamated. The other is copper, iron, silver, gold, or platinum; the last being preferred for very powerful batteries, and admitting of being replaced by coke. For telegraph-batteries, amalgamated zinc and copper, or zinc and silver, are generally employed; and the liquid in which they are dipped is diluted sulphuric acid—which dissolves the zinc, but does not affect the copper or silver. Let us suppose copper and zinc to be the metals selected. We have it in our power to take all the copper we propose to employ, in one large sheet, and all the zinc in another; or we may cut down each sheet into many small ones. *The quantity* of electricity evolved by a voltaic battery is chiefly determined by the size of the plates made use of; but if we take a single sheet of zinc, however large, and a single sheet of copper, we find *the intensity* of the electricity they evolve exceedingly feeble. If, on the other hand, we cut down each of the large plates into several smaller ones, and arrange these so that the copper and zinc shall be placed alternately, in a way to be presently described, we find the quantity of the electricity much diminished, but its intensity greatly increased. Unless the intensity be considerable (although it need not be very great) the electricity cannot force its way along a great length of conductors; and, if its quantity be not great, its effect will be but momentary. Plates, however, a few inches square, supply a sufficiency of electricity for a long telegraph line; and from twelve to sixty pairs of such plates are as many as are required. The exact number needed will be determined by the distance which the electricity is to travel. By varying the number and size of the plates, as well as the strength of the acid

in which they are dipped, the quantity and intensity of the electricity may be modified through very wide limits.

A voltaic battery, strictly speaking, consists of associated pairs of dissimilar solids, such as zinc and copper. A single pair, or *simple* voltaic circle, like a single cannon in an artillery battery, is but an elementary portion of a voltaic *battery*, which is constructed by arranging several pairs together. The simplest voltaic battery, then, will consist of at least two pairs, *i. e.* of four plates, two of zinc and two of copper. In arranging these, two glass beakers or drinking tumblers are taken, and placed side by side, half full of diluted sulphuric acid. A wire is then soldered to one of the zinc plates, and a corresponding wire to one of the copper plates, and one of these plates is placed in each of the tumblers. The second zinc plate is thereafter soldered by one edge to the second copper plate, so as to form one continuous surface of metal. The compound plate thus produced is then bent over, so that the soldered edges form the summit of an arch, which resembles a saddle, with one flap consisting of copper and the other of zinc. This metallic saddle is placed astride of the approximated edges of the tumblers, so that the zinc flap dips into the vessel in which the first copper plate with the wire is immersed, and the copper flap into the tumbler containing the zinc plate with its wire (*Fig.* 1.).* If we wish to enlarge the

Fig. 1.



* *Fig.* 1. A voltaic circle or battery of three pairs, consisting of three plates of copper and three of zinc, placed in as many tumblers containing dilute sulphuric acid. The coppers are shaded, the zincs unshaded. c, wire

battery, we take additional tumblers, and such copper-zinc arches as have been described, connecting the vessels, half filled with dilute acid, by the metallic bridges which dip on either side into the liquid; taking care also that all the zinc semicircles or saddle-flaps shall be turned in one direction, and all the copper ones in the opposite, so that zinc and copper succeed each other alternately, from the first tumbler at one end of the range to the last at the other. In actual practice, porcelain, or wooden, or gutta percha cells or troughs are generally substituted for glass vessels, and the pieces of zinc and copper are not soldered together, but only connected by moveable wires and binding screws. But these mechanical adjustments are only for greater economy and convenience; and the battery remains, in principle, identical with the arrangement described.

Such, then, in its most skeleton and simple form, is the apparatus which is to furnish the *primum mobile* of our telegraph. Although each zinc and copper pair contributes to the power of the battery, the whole electricity generated by it manifests itself only at the detached zinc plate at the one end of the battery, and the detached copper plate at the other. A battery thus resembles a compass-needle or bar-magnet, which appears to manifest its inherent magnetism only at its opposite poles; although, in reality, it is magnetic throughout its entire length. In the practical application of such a battery, accordingly, no account is taken of any portion of it but the terminal zinc and copper plates, to each of which a wire is attached. To these plates all the intermediate ones convey the electricity which they respectively set free; so that we may, after all, properly enough conceive the battery as consisting of a single plate of zinc and one of copper. Such an embryo battery—or, rather,

---

from the free copper at the one end of the battery. z, wire from the free zinc at the opposite end. The copper-wire is also called the *positive pole:* the zinc-wire the *negative pole.*

voltaic pair—might, indeed, be used for working the telegraph, where the distance was very short; and it is within possibility that a single voltaic pair of strongly contrasted solids, immersed in a rapid solvent of one of them, will yet be found sufficient for working the longest existing or conceivable telegraph line. As it is, the intermediate pairs of the voltaic batteries in actual use are introduced only to give the requisite intensity to the electricity generated. They may be ignored in our further discussion; and our telegraph-battery will resolve itself into a piece of copper and a piece of zinc, immersed, without touching each other, in the same vessel of acidulated water.

It may assist some readers towards a better understanding of the reason, why only the two terminal plates of the largest battery are referred to, if we offer the following comparison. In every human being there is resident a living or vital force or power, so far analogous to the electrical force developed by a voltaic arrangement. Let us imagine persons of opposite sexes selected, to represent the unlike metals; a girl standing for the fair, white zinc; a boy for the dusky, red copper. Any equal number of girls and boys may be supposed taken, for example, twelve of both, and arranged alternately in a straight line, beginning with a girl at the one (for example, the right) end, and terminating with a boy at the other. To represent the arrangement of the zinc and copper plates in a battery, let the twenty-four individuals in the row join hands with each other, so as to form a continuous straight chain. The result will be, that of all the forty-eight hands possessed by them, only *two* will be free, namely the *right* hand of the *first* girl, and the *left* hand of the *last* boy. If we further imagine, that the effect of such clasping of hands were, that the living force of all the girls passed along the line, and became concentrated in the one free right arm of the first girl; and that conversely, the vitality of all the boys passed in the opposite direction, and became located and available in the one free left arm

of the last boy; we may realise what a voltaic battery is, as distinguished from a voltaic pair. In the battery, although the alternations amount to thousands, or millions, there is but one free copper, and one free zinc, like the one free right arm and the one free left arm, which alone would be available if all the pairs of men and women in the world were to arrange themselves alternately, according to their sex, and to join hands. By placing men and women together in this way, we cannot invest a single male arm with the masculine energy of all the men, and a single female arm with the feminine energy of all the women; but by arranging pieces of copper and zinc alternately, we *can* concentrate in the last copper the electrical power of all the coppers, and in the last zinc the electrical power of all the zincs. In particular, we thus increase the *intensity* of the electricity, which we have always more difficulty in elevating, than we have in increasing its quantity. The latter, in truth, is superabundant, as obtained from even a single voltaic pair.

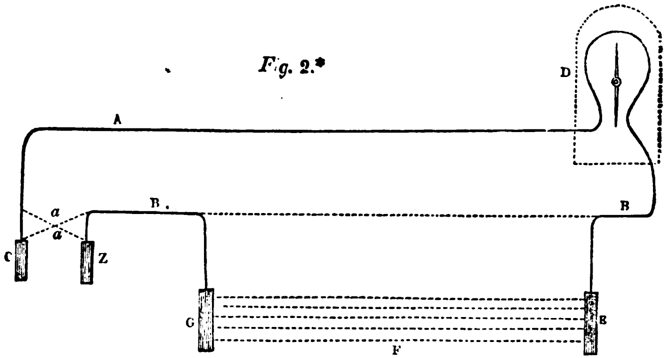
Our readers, then, will think of the free zinc as if it were the one disposable female arm, and strong as the arm of a giantess; and of the free copper as if it were the one disposable male arm, and powerful as a giant's; being careful, at the same time, to regard the giantess and the giant as possessed of *exactly* equal power. If we further suppose the opposite ends of a long wire to be grasped by each giant hand, and assume that the force passing along the wire will move an index to the right or to the left, according as the male or the female hand grasps the one or the other end of the wire, we shall realise the idea of the telegraph arrangement so far as the battery and conductors are concerned.

For the sake of simplicity and clearness in our further description, we shall suppose the battery described to be situated in London; and that our object is to send messages to Edinburgh, without communicating with any intermediate place. An iron wire, plated with zinc to keep it from rusting, is connected with

the *copper* plate of the battery, and then stretched all the way from London to Edinburgh, along wooden posts, erected some sixty yards apart. In order that the electricity, which is to travel along this wire, may not go elsewhere than to the northern metropolis, the wire is *insulated, i. e.* prevented from coming in contact with metallic conductors, moist wood, or other surfaces which would transfer the electricity along the posts to other wires that are generally stretched upon them, or to the earth. The insulation is effected by passing the wire through rings or short tubes of glazed porcelain, attached to the posts, so that the electricity has no choice but to move along the wire. At Edinburgh the wire is placed in connexion with the signal-apparatus, to be afterwards described; and then is brought back to London through separate porcelain tubes along the posts as before, and finally terminates at the detached *zinc* plate of the battery. In the arrangement described, which is the earliest and most easily understood form of telegraph, it will be observed that the zinc and copper plates of the battery at London are connected by one unbroken metallic wire, which extends to Edinburgh, bends back there, and returns to London (as shown in *Fig.* 2., page 28.).

The wire, however, does not return to the latter city, in order to provide a channel for messages being sent from Edinburgh to London, as well as from London to Edinburgh. Without this returning double wire (as we shall call it), or an equivalent arrangement of conductors, it is impossible to telegraph from either town to the other, even if it were thought sufficient or desirable to send messages only from one of them. It will appear from this that there must be something peculiar in the way in which electricity travels along the telegraph-wire. We have compared it to the transmission of a fluid; but the wires cannot convey it as pipes do gas or water, otherwise there would be no occasion for the return-wire. A tube extending from London to Edinburgh, and filled with air or water, might be

Fig. 2.*



* *Fig.* 2. Diagram of telegraph supposed to have a single message-sending and receiving station.

C, last copper, and Z, last zinc of battery at sending station.

A, upper wire suspended on posts, on the aërial telegraph lines, and insulated by being passed through porcelain rings; buried in the ground on the subterranean telegraph lines, and insulated by being covered with gutta percha.

D, long loop of covered wire, continuous with A, and coiled many times round the magnetic needles of the signal-index (shown in profile in *Fig.* 3. p. 39.) at the receiving station.

B, lower or return-wire, a continuation of the upper one, which in the *theoretically* simplest telegraph returns, as shown by the dotted line, to the last free zinc of the battery. In actual practice the return-wire is cut short after bending back from the signal-index at the receiving station, and is made to terminate in a plate of metal E, which, in the land telegraph, is buried in the earth, and in the aqueous or marine telegraph is plunged beneath low water-mark in the channel to be crossed.

F, interposed mass of earth or water, separating giving and receiving station.

G, second buried or submerged plate sunk near the sending station, and communicating by a wire with the battery.

By means of a moveable handle not represented in the diagram, A can be connected with the copper of the battery, and B with the zinc (as indicated by the vertical *unbroken* lines proceeding from C and Z) when the index-needle at D moves to one side; or B can be connected with the copper, and A with the zinc (as shown by the *dotted* lines *a a*), when the index moves to the opposite side: or the wires may be disconnected from either end of the battery, and the index stands vertically, pointing to neither side.

employed to telegraph from the Metropolis to the Northern Capital, as an air-tube is actually employed at the railway tunnels near termini; and but one tube would be needed, if messages were sent only from London. It is very different with electricity; it must not only travel to Edinburgh, but it must come back to London—otherwise nothing can be recorded at Edinburgh; so that the communication must be as complete between Edinburgh and London, although the latter only is to send messages, as between London and Edinburgh.

The explanation of this peculiarity, if we avoid the niceties of electrical theory, may be said to be found in the fact, that no electricity leaves the battery till its terminal zinc and copper plates are *connected* by a wire or other electrical conductor. It is not as if one wire were sufficient at least to carry the electricity from London to Edinburgh. Our electrical messenger is like a government courier—who does not start till he is satisfied that there are relays of horses to make certain his homeward, as well as his outward journey. If there be not a return-wire, or equivalent arrangement, the electricity never sets off from London! or, rather, there is in truth no electricity to set off in any direction, till the zinc and copper at that starting place are connected. Till a communication is effected between them, the battery is equivalent only to a loaded gun. The completion of the connection is like the fall of the trigger which fires the charge. In a moment the battery discharges its electricity, which, with inconceivable rapidity, passes, by the shortest route it can find, from the copper plate, at the one end of the battery, to the zinc plate at the other. No shorter route, however, is provided for it than the insulated wires, so that in the case supposed, although the plates to be connected are only a few inches apart, the electricity which leaves one of them must travel from London to Edinburgh and back again before it can arrive at the other! Our newest telegraph in this respect is like Noah's most ancient one. His raven "*went*

to and fro," and his dove "*returned*" to the Ark with the olive-leaf in her mouth.

If we look, however, a little more closely into what happens, we shall find something still more curious than we have yet indicated, in the movements of the electricity produced by the battery. We have hitherto represented matters, as if only one current of electricity swept along the wires; but in reality, if we are to speak of currents at all, we must acknowledge at every moment two, moving in opposite directions. Electricity, like magnetism, always displays itself as a two-fold force. A bar-magnet or compass-needle has magnetism at each pole or extremity. The magnetism of its north pole has the same powers and intensity as the magnetism of its south pole, if we test these by their action on a third body, such as a piece of non-magnetic iron. But if we try two bar-magnets against each other, we find that the south pole of the one attracts the north, but repels the south pole of the other, and *vice versâ*; and if a north and south pole be placed together, instead of the magnetism being doubled in intensity, it is reduced to zero—or what we may call the northern magnetism neutralises the southern magnetism, and all indications of free magnetic force cease.

Electricity exhibits exactly similar phenomena. In the very act of becoming free, as when it is evolved from a voltaic battery, it separates into two forces—identical in nature, but opposite in the direction of their manifestation—whose intensities and powers are equal, and which, like the northern and southern magnetisms when they meet, instead of yielding a double electrical force, neutralise and annihilate the powers of each other. To the two electricities the names have been given of *positive* and *negative* respectively,—an unfortunate nomenclature, as it almost unavoidably conveys the impression that the one is more positive or potent than the other; whereas the negative electricity has as positive an existence and as substan-

tial powers as the opposite electricity—and neither, in fact, can be produced without the development of the other. The terms in question, like the older ones *vitreous* and *resinous*, are to be regarded, in short, as quite arbitrary, and might be replaced by any other words or signs:—though we leave medical men to explain the account which a wilfully ambiguous critic has given of *their* electrical acquirements: viz. that their knowledge of electricity is chiefly of the negative kind!

The twofold magnetism in a bar-magnet has been likened to a double-headed arrow at rest, pointing in two opposite directions, like a wind-vane. The twofold electricity liberated from a battery may be likened to a similar double-headed arrow,—not at rest, however, but rapidly elongating itself in opposite directions, so as to separate its two heads or points, further and further from one another. The one arrow-head represents positive, the other negative, electricity. Though they separate, they are never disunited. At first they move away from each other; but their paths are equivalent to semicircles of the same radius, and are in the same plane, so that they ultimately meet—and in the act of meeting, each arrow-head destroys the other, and a harmless non-electric circle is completed. The Egyptian hieroglyphical serpent, devouring its tail, might be accepted as the symbol of the closed electric circuit.

If we apply what has now been said to the telegraph, the necessity for the two wires will appear in a new light. When the plates of the battery, consisting of amalgamated zinc and copper, are merely placed apart from each other in dilute sulphuric acid, no change of any kind occurs. But if they are connected, as by attaching the zinc to the one end of the double telegraph wire, and the copper to the other end, the zinc immediately begins to dissolve in the acid; and simultaneously with this solution of the metal, and the evolution of hydrogen from the water, electricity in its twofold form is developed. At the

middle point in the liquid between the two immersed plates we may suppose the electricity to come into existence,—likening it as before to a double-headed arrow. Elongating themselves in directly opposite directions through the liquid, the one arrow-head speedily reaches the copper-plate on the one side, and the other arrow-head the zinc on the other. The arrow at the copper is positive electricity. If we speak of it as before, we shall say that a current of positive electricity flows from the copper along the telegraph wire to Edinburgh, and then returns to the zinc plate, where it may be regarded as stopping;—at the same time that a current of negative electricity travels from the zinc plate along the same telegraph-wire, in an opposite direction to that taken by the positive current, and may be considered as ending at the copper plate.

According to this view, the narrowest telegraph-wire may be compared to a railway with two sets of rails, along which trains (of positive and negative electricity) travel in opposite directions, in obedience to a statute which requires that there shall always be two opposite trains moving at the same time along the rails. We must further regard the wire, whilst conveying electricity, as traversed, not by solitary engines or a few carriages, but by trains occupying the entire length of the railway,—fresh carriages constantly setting off at the one end, and being detached at the other.

The necessity, however, for the double wire, is best seen when we revert to the notion of electricity travelling like a flying arrow. The route of the arrow is the wire, and the latter must be double, because the arrow itself is not an English cloth-yard shaft, which flies only in one direction: but such a two-forked thunder-bolt as the Greek sculptors placed in the clenched hand of Jupiter Tonans, which shoots east and west, or north and south at the same time, and the one bolt of which will not fly in one direction unless the other is equally free to move in the opposite direction.

What evidence, it may here be asked, is there to show that any thing substantial moves along the telegraph-wires? To this, as already implied, there is but one answer. No actual proof can be given of the passage of anything material. The flowing currents and the flying arrows are both purely imaginary: the one is an hypothesis, the other an illustration. But there is yet another mode of explaining the apparent passage of this invisible agent. It is, to be sure, quite as hypothetical as the other two; but it is, on the whole, more likely to be true, and it is therefore now preferred by most men of science. Our discussion would, consequently, be incomplete if we did not refer to it.

Accepting this view, the metallic conductor, such as the telegraph-wire which connects the terminal plates of the voltaic battery, is not a highway along which electricity travels. The wire exhibits electrical phenomena throughout its entire length, only because its connexion with the zinc and copper wetted by the acid, produces, for the time, a new arrangement of its own particles or molecules, which invests the wire with new properties,—those, namely, which we call electrical. Nor is there any thing extreme or anomalous in this assumption. The whole of physical science bears testimony to the fact that we cannot alter the arrangement of the component parts of a mass, without inducing a corresponding change in the qualities of the mass which those atoms build up. Soot and wood charcoal, coke and black lead, owe their different properties merely to a different arrangement of identical particles of carbon; and a further modification of these invests them with the utterly diverse and characteristic attributes of the diamond. But the electrical differences between two wires, one acting as an electrical conductor and the other not, are not greater than the optical differences between a lump of coke and a diamond crystal,—or between carbonate of lime, uncrystallised in chalk, and crystallised in pellucid Iceland spar. We can set no limits,

indeed, to the extent to which modification of molecular arrangement will affect the properties of a mass.

Nor is it any objection to such a view, that a metallic wire is a rigid solid, the component particles of which are so locked together as not to admit of motion upon each other, or change of relative position. The opinion once entertained that only liquids and gases permit the mobility requisite for alteration in molecular arrangement, is now universally abandoned. And indeed the expansion and contraction of a mass of metal under the influence of heat and cold is a sufficient refutation of it. The Britannia tubular iron bridge creeps, like a huge snake, backward and forward several inches during the twenty-four hours of a midsummer day. The massive glacier changes, from an aggregate of minute crystals of packed snow, into a mountain of clear ice. Every school-boy is familiar with the same phenomenon as developed during the formation of a slide on a surface of snow. In copper mines, an iron hammer, dropped into a pool saturated with cupreous salts, is found, after the lapse of years, converted into a hammer of copper:—the whole of the iron has been extracted, and its place supplied, to the very centre, by copper,—without the form or the bulk of the solid having altered during the process of transmutation. During the production of steel from iron, in like manner, the latter is embedded in charcoal powder and the whole made red hot. The charcoal then penetrates into the solid iron, and impregnates its entire mass.

These examples (and many more might be added) apply to alterations in the structure of solid masses, much greater than we need assume to occur in an electrical conductor. So that we need not hesitate to admit, as possible, molecular changes of a more simple character. The change that probably happens in the telegraph-wire is believed to resemble what we can pretty confidently affirm to take place in magnetised iron, where the characteristic phenomena are more readily observed, and

are more familiar than in the case of electrical conductors. A bar-magnet, or compass-needle, appears at first sight to possess magnetic powers only at each end, or pole. On closer examination, however, it is found to possess the opposite northern and southern magnetisms, in alternate succession, throughout its entire length. We may compare it to one of the lines or stripes of a chess board, or tesselated pavement, made up of *alternate* coloured pieces. The colours, however, must be only two,—for example, blue and yellow; the first square, or tessera, being of the one colour, and the last of the other. A piece of non-magnetic iron becomes temporarily magnetic if brought into the neighbourhood of a permanent magnet, such as a loadstone: and, while thus magnetic, the iron exhibits the same alternation of oppositely magnetic particles which the compass-needle does. We may liken non-magnetic iron to an aggregate of compound green particles. It becomes magnetic in consequence of each of these separating into a blue and a yellow particle,—which follow each other alternately in rows. When the iron ceases to be magnetic, in consequence of the withdrawal of the loadstone, the result is as if the blue and yellow particles united again, and the whole became uniformly green. In like manner, the wire which connects the zinc and copper of a voltaic battery is believed, in consequence of its junction with these metals whilst they are affected by the acid, to have induced in it, throughout its entire length, a succession of alternate electro-positive and electro-negative points, or particles possessed of positive and negative electricity respectively. The arrangement is of exactly the same kind as that of the magnetic bar—only it is an alternation, not of the opposite magnetisms, but of the opposite electricities. They remain separate so long as the constraining force of the battery is exerted upon them; but, the instant the wire is disconnected from it, the separate electricities unite, and all electrical phenomena cease. We may liken the telegraph-wire when disconnected from the battery, to a thread on which

purple beads are strung together, as on a necklace. When the wire is connected with the battery, each purple bead separates into a red (positively electric) and blue (negatively electric) one. The red and blue beads now succeed each other alternately along the line, beginning with a red bead at the last copper of the battery, and ending with a blue one at the last zinc; and they remain separate, whilst, in the language of another theory, electricity is passing; but they coalesce again into the compound purple spheres, so soon as the connexion with the battery is interrupted.

According to this view, there is no travelling of electricity charged with messages from one station to another. The message telegraphed from London to Edinburgh is not wafted by electricity which speeds from the former, inscribes its hieroglyphics at the latter as it rushes past, and fleets back to London; but the telegraph-wire, with inconceivable rapidity, merely arranges its own constituent particles, from end to end, in alternate electro-positive and electro-negative molecules; and the index on the Edinburgh dial-plate is affected only by the small portion of the wire which surrounds the gnomon. It is as if a row of men were placed side by side from Edinburgh to London, with signal-flags in their hands. The flag shown as a signal at Edinburgh has not been passed along the line. No man has stirred further than to observe the flag shown him by his neighbour on the one side, and to show a corresponding flag to his neighbour on the other. The flag displayed at Edinburgh was there from the first, though unfurled, and remains there concealed, till the next message is telegraphed from man to man.

The reader can select whichever of the explanations now given he prefers, or can devise theories for himself, or dispense with any. But the ultimate and only important *fact* in reference to the telegraph is, that, by the marvellously simple device of dissolving a few pieces of metal connected with a long wire, we can develope instantaneously, a thousand miles off, a force

which will speak for us, write for us, print for us, and, so far as the conveyance of our thoughts is concerned, annihilate space and time. This annihilation is not of course complete, but in reference to practice it may be called so. Shakspeare's Juliet refers to—

> "The lightning which doth cease to be,
> Ere one can say it lightens."

The exact velocity of electricity along a copper wire suspended in the air, according to Wheatstone, is 288,000 miles in a second. It is calculated, accordingly, that we could telegraph to our antipodes in rather less than the five hundredth part of one second of time! But when a wire is buried in the earth, or sunk in the ocean, the speed is considerably retarded, as will be shown in the sequel. Yet, when slowest, it is swift enough.

The most impatient of correspondents may be satisfied with this velocity; and we may now inquire in what way electricity is made to produce signals. In discussing this we shall recur to the provisional theory adopted at the outset, that electricity flows in currents; and, in conformity with the universal practice of expositors of electrical phenomena, write as if there were but a single current of positive electricity flowing along a telegraph-wire. The other and opposite negative current may conveniently be disregarded, as in navigation a compass-needle is referred to as if it had but one pole, pointing to the north.

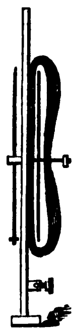
Having secured the means of transmitting at will a current of electricity with great velocity, it remains to determine what phenomenon we shall cause it to produce at the distant station.

The phenomena most easily produced by electricity are *magnetic* ones; and these, accordingly, are generally preferred as the sources of signals. The electric telegraph, indeed, remained an unrealised idea in the minds of ingenious men, till the famous Danish philosopher Oersted discovered, that a current of electricity, even though of very small intensity, if

passing near a compass-needle poised on a pivot, will cause the needle to change its position, and point in a new direction. Let the telegraph-wire, for example, whilst connected with a battery, be placed so that the needle of a mariner's compass shall be directly below or above and parallel to the wire, and the needle, no longer "true to the pole," will whirl round and stand east and west, instead of as before north and south. It depends upon the direction in which the current of electricity is sent, which pole of the compass-needle points east or west. Let the telegraph-wire, stretching from London to Edinburgh and back again, be considered as consisting of an upper and a lower wire. If the end of the upper wire be connected with the copper extremity of the battery, whilst the end of the lower wire is connected with the zinc, the current of positive electricity (the only one of which we now take cognisance) will flow along the upper wire to Edinburgh, and return by the lower one to London. If the upper wire be now attached to the zinc, and the lower to the copper, the current will travel north by the lower wire, and come south by the upper. Now, without entering into details for which we have not room, and which are not essential to the comprehension of the telegraph, it may suffice to say, that the pole of the compass-needle, which points east if the electrical current passing near it be sent in one direction, points west if it be sent in the opposite one: while, if the passage of electricity be discontinued, the needle resumes its original position. We have it thus in our power to cause a compass-needle to move to either side at will; and we can bring it in a moment to rest. These effects are produced still more strikingly if the wire, instead of being stretched above or below the compass-needle, be coiled many times round the compass-box or case containing the magnetic needle. The wire, in that case, is covered with thread; which allows its coils to be put close together, without risk of the electricity passing *across* from coil to coil where they touch, as it would do, if the thread, which is a non-conductor, did not insulate the electricity.

It is more convenient that the magnetic needle should originally stand vertically, so as to move from right to left, or *vice versâ* —like the index of a wheel barometer, than that it should revolve in a horizontal plane like a mariner's compass. It is also much more easily moved, if the effect of the earth's magnetism on it be neutralised. This is done by placing *two* magnetic needles on the same axis, with their poles reversed, so that the north pole of the one is opposite the south pole of the other. Such an arrangement, if the needles are of equal power, has no tendency towards one point of the compass more than another; and, by making what are to be the lower ends of the needles somewhat heavier than the opposite extremities, the needles, when not under the influence of electric currents, will at once resume their vertical position.

Fig. 3.



The one of the two needles which is to act as the visible index appears in front of a dial plate; the other, surrounded by the coil of covered wire, which is continuous with one of the telegraph-wires, is placed behind the dial. (*Fig.* 3.*) An arrangement of this kind is provided at Edinburgh, the upper telegraph-wire being drawn out there into a long loop, which consists of

* *Fig.* 3. View in profile of signal-index shown in front in *Fig.* 2. p. 28. The vertical line, to the left of the diagram, indicates the visible magnetic needle which shows on the front of the dial-plate, and, by its movements to the right or to the left, makes the signals. This needle has (we shall suppose) its *north* pole pointing upwards. To the right of it is the dial-plate, seen in profile; and further to the right, or behind it, the second vertical line represents the concealed magnetic needle with its *south* pole upwards, and throughout its entire length surrounded by a coil of covered wire, returning on itself many times, and forming a long loop continuous with the upper or insulated telegraph-wire. Both needles are on the same axis, and move together, and the electricity acts directly on each, so as to deflect them to the right or to the left, according to the direction in which the current is sent along the coil. In later arrangements only the concealed needle is magnetised, the other, which is not magnetic, acting simply as a pointer.

soft copper wire covered with silk. This is wound round the concealed magnetic needle, so that a current of electricity moving along the upper wire follows the coiled loop, moves the needles in passing, and returns to London. At London, for a reason to be mentioned immediately, there is a similar loop or coil of covered copper wire surrounding a double magnetic needle, and then rejoining the upper main wire from which it proceeded. From the copper end of the battery, a wire is conducted to one of the strands of this coil, and soldered to it. From the zinc end a wire also is conducted, which is soldered to the lower telegraph-wire. The current, setting off from the London battery, deflects the needles at London and at Edinburgh before it returns to London. That the needles may be deflected to either side at will, a contrivance is supplied for cutting off and letting on, as well as for reversing, the electric current from the battery. It is a little difficult to explain distinctly this important portion of the telegraph. The following description, however, will perhaps make it sufficiently clear. Let the upper end of the double telegraph-wire at London be marked A, and the lower end B. If A be connected to the copper of the battery, and B to its zinc, the current of electricity, setting off from A, and returning to B, moves the index-needle to one side, for example to the left. If the arrangement be now reversed, so that A is connected to the zinc, and B to the copper, the current flows from B to A, and moves the needle to the right. (*Fig.* 2. p. 28.)

In actual practice, however, the wires are not shifted from the zinc to the copper, but are *cut across* between the battery on the one hand, and the telegraph-wires, and coil round the magnetic needles on the other. The gap thus made is left vacant when no message is to be sent. When a signal is to be transmitted, a metallic cylinder is moved by a handle so as *to fill up the gap*, and establish continuity between the wires and the copper and zinc respectively of the battery. This bridge,

however, is so contrived, that, when the handle which controls it is moved to the left, it stretches in such a manner as to connect the end A of the telegraph-wire with the copper, and the end B with the zinc, and the needle moves to the left. When the handle is moved to the right, it shifts the cylinder or bridge so as to establish a communication between A and the zinc, and between B and the copper; and the needle moves to the right. When the handle is placed vertically the current is cut off from both wires.

It only remains that an arrangement be made between the parties in Edinburgh and London, as to *the signification* of these deflections of the needle. This having been settled, the message-sender in the Metropolis, seated before his dial, moves the handle which determines the transmission and direction of the electricity along the wires. Every motion of the handle, to the right or to the left, causes the index-needles at London and Edinburgh to move simultaneously to the same sides. We may suppose, for example, that an answer in the negative is to be telegraphed from London to an interrogation from Edinburgh. It has been pre-arranged that one movement of the needle to the left shall signify N, and one to the right O. The respondent accordingly moves his handle to the left; thereby transmits the current of electricity in such a direction as to move the index-needle at Edinburgh to the left also; and so represents N. He then places the handle vertically, so as to cut off the current and permit the needle to resume its vertical position; and, after a brief pause, carries his handle to the right, which moves the Edinburgh needle also to the right,—and indicates O, thus completing the answer.

The signal-dial at London is not essential, if London is not to receive messages; but, as it must be provided with a view to their reception, it is so arranged that the electricity moves its index-needle before it passes on to Edinburgh. The party transmitting a message has thus figured before him deflections

of the index-needles identical with those which his correspondent is watching and deciphering, at the same moment, hundreds of miles away.

Only two movements, it will be observed, can be effected: but it is easy to make them represent the whole alphabet, and to telegraph rapidly, although every word be spelled letter by letter. Man, moreover, is by his natural-history definition one of the *bimana*, and by consequence two-handed. Two dials can, therefore, be arranged side by side, with coils and index-needles for each, and handles to be managed by either hand. Four movements are thus made possible; and for most purposes these supply an ample abundance of signals. It does not form part of our present purpose to explain these,—as their employment to represent letters, numerals, words, paragraphs, or the like, is quite arbitrary, and involves nothing electrical. We give a specimen, however, of one of the telegraph alphabets:—

A, one movement to the left	N, one right
B, two left	O, two right
C, three left	P, three right
D, four left	Q, four right
E, one left, one right	R, one right, one left
F, one left, two right	S, two right, one left
G, one left, three right	T, three right, one left
H, two left, one right	U, one right, two left
I, two left, two right	V, two right, two left
J, two left, three right	W, three right, two left
K, three left, one right	X, one right, three left
L, three left, two right	Y, two right, three left
M, four left, one right	Z, one right, four left.

We have provided hitherto only for messages being despatched from London, but we must make provision also for London receiving them. Edinburgh, conversely, must be made a message-sending as well as message-receiving station, and in truth, this double privilege must be conferred on all the sta-

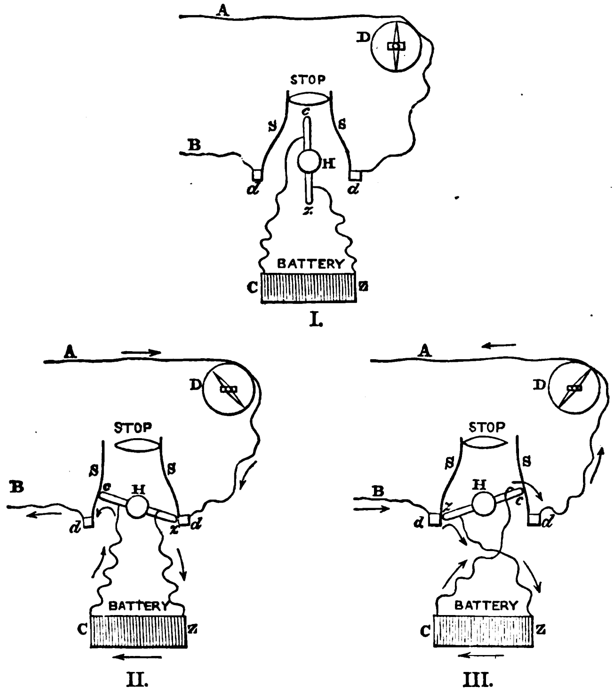
tions along the line of telegraph. For this end, an arrangement somewhat more complex than that already described, but still very simple, is carried out in such a way that when station M is sending a message, no electrical current from stations N, O, P, &c., can reach its indicating dial; whilst when M is not sending a message, an open pathway is provided along the wires for despatches from N, O, or other stations.

To secure this, the end A (page 28) of the upper wire is joined to the fine silk-covered wire forming the "coil," which passes round the magnetised needle, and thereafter is attached to a brass spring resting on a metallic stop. The end B of the wire (page 28) is connected to a similar spring resting on the same stop. (See *Fig.* 4. I. II. III.) Between the two springs is placed a wooden barrel or cylinder, in which two metal pegs are stuck, the one joined by a wire to the copper and the other to the zinc of the battery. These pegs are of brass; but it will be convenient to name them after the ends of the battery to which each is permanently attached, as the *copper* peg and the *zinc* peg. The cylinder is controlled by a handle which may be compared to a stop-cock. When this is vertical, the two springs rest on the stop as described, and the pegs in the barrel do not touch the springs. (*Fig.* 4. I.) The stop then acts as a bridge, filling up the gap between the ends A and B of the wire, and the apparatus is adjusted to receive signals from the distant stations.

When the handle is moved to the one side, the *copper* peg attached to the barrel pushes the spring to which B is joined away from the stop, and so interrupts the circuit, but the *zinc* peg immediately after touches the spring to which the coil and A are connected, placing the battery in the gap, and moving the needle to the left. (*Fig.* 4. II.) When the handle is moved to the other side, the *copper* peg touches spring B, and the *zinc* peg touches spring A, placing the battery in the gap as before, but with the current in the reverse direction, so that the needle moves to the right. (*Fig.* 4. III.)

From what has been said, it will be understood that signals telegraphed from any one station to any other will be contemporaneously exhibited at every station. For the whole of

Fig. 4.*



* *Fig.* 4. Diagrams illustrating arrangement for changing channel and direction of current. The letters are the same in I. II. III.

The apparatus in actual use is more complex than that described, but does not essentially differ from it.

I. *Arrangement for receiving Signals.*

A. Upper telegraph wire.

D. Long coil attached to A, wound round magnetic needle, and ending in right metallic stud *d* and spring S.

B. Lower telegraph wire attached to *left* stud *d* and spring S. The springs press upon the *stop*, which is equivalent to a metallic bridge.

the stations are included in one circle of conductors, which carry the electricity round all the indicating apparatus within the circle; and the current cannot move one index without moving all. It is impossible, therefore, if a common alphabet be used along the line, to conceal from the whole of the stations what may be intended only for one. All that can be done, unless a separate series of wires or other conductors is supplied for every station, is to signify what place the message is directed to, so that other stations need not be at the trouble of deciphering the signals, or in cases where secrecy is desired to employ a cipher.

In addition to the arrangements for producing and interpreting signals, it is plainly necessary that we should have

---

H. Wooden cylinder moved by a handle.

c. Brass peg fixed into H, and permanently connected by a wire with *copper* end C of battery.

z. Similar brass peg permanently connected by a wire with *zinc* end Z of battery. These pegs are insulated by the wooden handle, so that a current cannot pass from the one to the other across or through it.

The battery is not in action, as H prevents the current passing from *c* to *z*.

If a current come from a distant station along A or B, it crosses by the *stop* from the one wire to the other, moving the needle within D as it passes.

II. *Arrangement for sending Signals.*

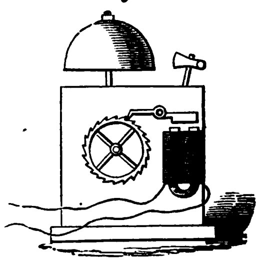
H. Handle turned so that peg *c* touches left-hand spring, detaching it from stop, whilst peg *z* touches stud *d* of right-hand spring. The battery is now in action, and the arrows show the direction of the current. From C, the copper end of the battery, it passes, by peg *c* and the left stud and spring, to lower wire B, by which it travels to distant receiving-station, returning from it, by upper wire A, right spring and stud, and peg *z*, to Z, zinc end of battery, moving its own as well as the distant needle to the *left.*

III. *Arrangement for sending Signals with current in reverse direction of* II.

H. Handle reversed so that *c* now touches *right*-hand spring and detaches it from *stop*, whilst *z* touches left-hand stud. The current from C now passes by right stud and spring to upper wire A, returning by lower wire B to Z, and moving the needles to the *right.* The wires do not touch each other where they cross.

some contrivance for calling the attention of the parties in attendance to the dials, when a message is about to be sent. Where special clerks are employed, the "click" of the needles is sufficient, but at other places warning is given by a bell, which a very ingenious application of electricity is made to ring. Electric currents not only deflect permanent magnets, such as the compass-needle, but confer magnetism upon non-magnetic iron. If a copper wire, therefore, be coiled round a rod of malleable iron, and a current of electricity be sent along the wire, the rod becomes a magnet so long as the current passes, and loses magnetism when the current ceases. This magnetising power of electricity is turned to account in the telegraph. An ordinary alarum, or the striking machinery of a common clock, wound up so that the hammer would strike and ring the bell if one of its wheels were not locked, is placed at every station. This wheel is locked by an iron rod, which is balanced on a centre, and so arranged that one end falls into one of the notches between the teeth on the circumference of the wheel. The other extremity of the rod is placed opposite, and close to the ends of a horse-shoe of malleable iron, which is surrounded by a coil of covered copper wire closely twisted round it, and connected by its ends with one of the telegraph-wires. If a current of electricity be sent along the telegraph-wire, it circulates round the horse-shoe, and converts it, for the time, into a powerful magnet; which accordingly pulls towards it the free extremity of the iron rod, and thereby shifts the other end out of the notch in the toothed wheel. The bell immediately begins to ring, as the unlocked wheels revolve by the action of a spring or a weight; but, as soon as the current is stopped, the horse-shoe ceases to be a magnet; the rod is no longer attracted, but

Fig. 5.



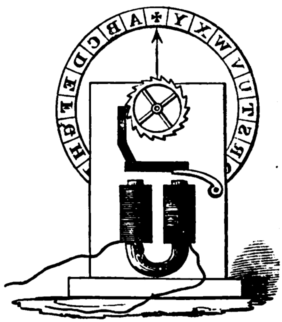
falls back into the notch and stops the bell. (*Fig.* 5.*) Under this arrangement, the bells at every station would ring simultaneously, although only one was intended to be warned; and the current that rings the bells would also move the index-needles, though only for a moment. On most telegraph lines, however, a separate set of wires is provided for the bells, so that they are rung without affecting the needles. A separate wire, also, is sometimes furnished for every station, so that each bell can be rung independently of the others: but such arrangements necessarily add much to the cost of the entire telegraph.

The magnetising power of electricity is also applied to produce visible as well as audible signals. The following is one of many such arrangements. A horse-shoe, which becomes alternately magnetic and non-magnetic, as an electrical current does or does not circulate round a copper wire coiled about it, alternately lifts and lets fall an iron lever, which, like the beam or piston of a steam-engine, gives a rotatory motion to a wheel; or, as in the cut (*Fig.* 6.), the horse-shoe depresses the lever, and a spring elevates it. This wheel carries an index, which travels over a dial round which the letters of the alphabet are engraved. The current must be alternately interrupted and continued, to keep the wheel revolving. When the current passes along the wire, the index moves from the letter at which it is pointing to the next. The current is then cut off; and, when it is restored, the index moves on to the succeeding letter; or, as in the drawing, the index moves when the current is cut off, and stops when it is let on. A key, like those of the organ or piano,—alternately

* *Fig.* 5. Railway alarum or signal-bell, seen from behind. It is wound up ready to strike, and then locked as shown in the drawing by a steel lever or *detent*. To ring the bell, a current of electricity is sent along the wires, which are wound in many coils round the horse-shoe. It becomes a magnet, and pulls towards it the one end of the lever, which lifts the other end or detent out of the notched wheel. The bell is stopped by cutting off the current, which allows the detent to fall back into a notch.

depressed and allowed to ascend—furnishes the means of interrupting and renewing the current. This arrangement has been called the step-by-step telegraph; as for each touch of the key the index makes only one step; namely, from the letter it is at, to the next. (*Fig.* 6.*) It has the convenience, too, of using the old familiar alphabet, instead of arbitrary deflections of needles, and is alleged to possess other advantages, which, however, are very questionable.

Fig. 6.

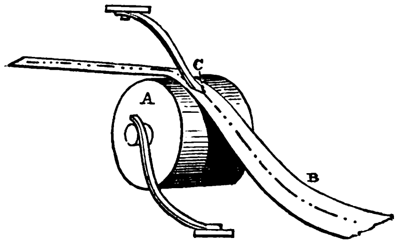


A third method of electric signalling is to effect chemical decompositions by the current. One such electro-chemical process is the following. A ribbon of paper, soaked in a mixture of nitrate of ammonia and prussiate of potash, is moved by clockwork over a metallic wheel or cylinder connected with one end of the divided wire. The other end of the divided wire terminates in a fine steel point, which presses on the paper as it passes over the wheel. The current is made to circulate from the steel point through the ribbon of paper to the wheel, and as the ribbon moves forward, the solution with which it is impregnated is decomposed, and dissolves a minute amount of the iron of the steel, producing Prussian Blue, and forming a blue mark, whose length is dependent upon the duration of the current. With this arrangement, the current, if constantly

* *Fig.* 6. One of the step-by-step telegraphs, represented as if the dial were transparent and seen from behind. The horse-shoe becomes a magnet, when the wires are conveying an electric current, and pulls down the lever. When the current is interrupted, the spring at the right-hand side raises the horizontal bar, which, by elevating the bent rod, working by its wedge-like end into the notches of the wheel, moves the index represented by a dotted arrow. By attaching a bent rod with a hooked end to the other extremity of the horizontal bar on which the horse-shoe acts, the wheel may be moved when the horizontal bar falls, as well as when it rises.

passing, would produce a continuous blue line on the paper; but the message-sender, by interrupting the current for longer or shorter intervals, causes it to imprint longer or shorter lines or strokes, and these are readily combined so as to form the following alphabet:—

Fig. 7.



A · —	J · — — —	S · ·
B — · · ·	K — · —	T —
C — · —	L · — · ·	U · · —
D — · ·	M — —	V · · · —
E ·	N — ·	W · — —
F · · — ·	O — — —	X — · · —
G — — ·	P · — — ·	Y — · — —
H · · · ·	Q — — · —	Z — — · ·
I · ·	R · — ·	

It is distinguished as the "*dot and dash*" alphabet, and is the invention of Mr. Morse, who employs it in his mechanical modes of signalling. By means of it, telegraphic messages can be sent at the rate of twenty words or more per minute. The

* *Fig.* 7. Method of electro-chemical signalling.

A. Metallic cylinder or wheel at message-receiving station, kept in revolution by clockwork when message is being received.

B. Ribbon of chemically prepared paper, which is slowly unwound from reel over A.

C. Steel point pressing on B.

A is in permanent connexion with the zinc end of the battery at the message-sending station. C is placed in connexion with the copper end of the same battery when the current is to pass, and disconnected when it is to cease, by means of a simple finger key, which is held down for a second if a dot is to be made, and for a longer period if a dash or stroke is intended.

electro-chemical process is the invention of Mr. Alexander Bain, of Edinburgh, whose great ingenuity is referred to elsewhere, and it is remarkable for its simplicity, the current not requiring reversal, but producing all the requisite signals by being cut off and let on at longer or shorter intervals.

Lastly, it may be mentioned, on this topic, that, from the first, much attention has been directed to the arrangement of an apparatus which should print as well as signal its messages. Many beautiful contrivances for this purpose have been devised and tried, and some of them are now in use. An arrangement similar to the step-by-step telegraph forms one of the printing machines. The horse-shoe electro-magnet, instead of turning an index, turns a disc or wheel, to the circumference of which an alphabet of inked printing-types is fixed. When the appropriate letter is brought opposite a ribbon of paper, the stroke of a hammer determines an impression; and in this way the message is printed letter by letter. In other printing-telegraphs clock-work is employed to turn the wheel bearing the types, and the electric current is only employed to commence and stop its motions at appropriate intervals, as in the case of the alarum-bell.

In the preceding description we have purposely referred to the simplest and most easily understood form of electric telegraph, where there is a wire reaching from the terminus at the one end of the telegraph-line, to the terminus at the other, and *back again.* In actual practice, however, one half of the wire is dispensed with, and its place supplied—by the earth! A century has elapsed since the very curious discovery was made, that the electricity of a charged Leyden jar or battery will pass instantaneously through a great length of moist earth. Voltaic electricity has more recently been discovered to possess the same power; and advantage has been taken of it in the following way. A wire is led from the last copper plate of a battery placed, let us suppose, at London, along the telegraph posts in the way already described, to Edinburgh, and is there

bent backwards towards London. Instead, however, of being carried along the posts a second time, the wire is now cut short and soldered to a large plate of metal, which is buried in the ground at some little depth. A comparatively short wire is also attached to the last zinc of the London battery, and soldered to a metallic plate, which is likewise buried in the ground. (*Fig.* 2. p. 28.) The arrangement is equivalent to a great gap or breach several hundred miles long in the double wire, filled up by moist earth. When the battery is in action, the electricity (positive) flows from the copper along the wire to Edinburgh, descends there to the one earth-plate (as it has been called), passes from it through the earth to the similar plate near the London station, and from it reaches the zinc of the London battery. The circulation of the electricity, in this way, is found to be even more rapid than when the double wire is furnished for its passage.

Good people have perplexed themselves with speculations as to why the electricity never wanders, misses its road, or fails to find its way back. But, as has been implied already, in the case of the double wire, electricity, like a prudent general, always takes care that a retreat be provided for, before it begins its march. Till an unbroken circuit of conductors connect the terminal plates of the battery, no electricity can be set free. It is not essential, however, that those conductors should be metallic; a column or stratum of moist earth will do quite as well as an iron or zinc wire. One half in length of the connecting conductors must be insulated; so that the electricity may be compelled to travel to the farthest point to which messages are to be telegraphed. But the other half of the conductors need not be insulated, and cannot be too large. The quicker the current can pass the better; and it will pass most quickly when conveyed by one or other of the two great electrical conductors which man has at his disposal—the solid mass of the globe, and the ocean with its tributary waters.

The last allusion leads us directly to the marine telegraph.

It requires, however, no detailed description—as it differs from the land telegraph only in having the space between the buried plates occupied by water instead of by earth. Broad estuaries or channels do not permit the insulated wire to be carried across by bridges. The wire, therefore, is embedded in gutta percha, or any other waterproof insulator, and sunk in the waters to a depth sufficient to secure it against fishing-nets, ships, anchors, or large sea-animals.

In this way it is conveyed from one shore to the other, and bending backwards after being connected with the index-needles, terminates in broad plates of metal sunk in the waves, close to each shore. Between the immersed plates on the opposite shores, the mass of water, though ever changing, acts in relation to electricity as if it were an undisturbed gigantic metallic wire. Theoretically, there is no limit to the ocean spaces which electricity may traverse in this way. Already, accordingly, schemes for telegraphing across the Atlantic, even where deepest, are triumphantly expounded to the wonder-loving public.

One of these, whether hopeless or not for immense distances, is so very ingenious, and so likely to succeed across limited spaces, that we cannot pass it unnoticed. Moreover, since the Atlantic cable ceased to convey messages, the claims of this, which may be called the *Wireless* Telegraph, to supplant the present submarine cables have been urged anew in the public journals. It dispenses, except to a very trifling extent, with wires, and carries the current *both ways* through moist earth and water. It is desirable, for example, to telegraph from the right to the left bank of a broad river. From the copper end of a battery on the right bank, a wire is carried to the shore (on the same side) and soldered to a plate buried in the river below water-mark. A wire is also led from the zinc end to a long coil of wire which ends in a metallic plate. This likewise is buried in the river below water-mark on the same right bank, but at a distance from the battery *considerably greater*

than the breadth of the river across which signals are to be sent. On the left bank two plates are immersed opposite those on the right bank, and connected by a wire. The electricity on leaving the battery has therefore the choice of two paths. It may either keep entirely on the right bank, passing from the one buried plate on that side to the other, and so back to the battery by the long coiled wire; or it may cross to the left bank through the water, traverse the wire on that side, return across the water to the right bank, and regain the battery by the shorter wire. The Thames has been actually crossed by electric currents in this way; the resistance to their passage by the water between the banks being less than that between the ends of the wires on the right and left bank respectively.

The permanent establishment, in September, 1851, of a quadruple telegraph-wire between the French and English coasts naturally excited much interest, but soon ceased to be an electrical novelty. It is generally named the *submarine*, but should rather be called the *transmarine* telegraph; for the triumph is not in having passed *below*, but *across* or *through* the Channel. So early as 1837, Wheatstone demonstrated the practicability of telegraphing under water. The only difficulty then lay in the rarity of good and easily-applied insulators. From the period, however, when the excellence and applicability of gutta percha as an insulator were demonstrated, it became certain that water would not be more difficult to telegraph through than a wet tunnel; and accordingly, in January, 1849, a skilful electrician, Mr. Charles V. Walker (superintendent of telegraphs on the South-Eastern railway) telegraphed for two miles under water (near Folkestone harbour), through that length of copper wire, which had been covered with gutta percha for use in the tunnels. This was strictly a *submarine* telegraph.

The only practical difficulty which attended the laying of a wire from Dover to Calais, or from Folkestone to Boulogne, was

the necessity for giving it a strength and solidity which should enable it to resist injury; and the question of strength was only a question of expense, which was solved as soon as the practicability of the scheme was demonstrated to men of capital. It would have been answered much sooner, had not the restrictions which the French government puts on the employment of telegraphs rendered it doubtful whether the scheme would prove remunerative.

In August, 1851, an experimental copper wire, covered with gutta percha, half-an-inch in diameter (including its covering), twenty-five miles long and weighted with lead, was laid between Dover, and Cape Gris Nez on the French coast. It completely answered, so far as transmission of signals was concerned; but in a few days it was cut or broken across. The cable which now stretches at the bottom of the sea, between Dover and Calais, is more than 24 miles long, and weighs about 180 tons. From the account of its construction given in the "Illustrated News" (Sept. 27. 1851), it appears that it consists of four copper wires, through which the electric currents pass, insulated by coverings of gutta percha: these are formed into a strand, and bound round with spun-yarn soaked in tar or tallow, forming a core or centre, round which are led ten iron wires, plated with zinc $\frac{5}{16}$ths of an inch in diameter, each welded into one length of $24\frac{1}{2}$ miles, and weighing about 15 tons. This immense cable, when wound together, formed a coil of 30 feet diameter outside, 15 feet inside, and 5 feet high. It was made in the short space of twenty days.

Each of the copper wires forms, along with the sea which acts as its return wire, a separate channel for sending messages; and the whole arrangement answers so well, that additional cables, similar in construction, have been largely constructed. Cannons have been simultaneously fired, on either side of the Channel, by the current from a battery some twenty-five miles distant on the opposite coast; but the batteries employed for

this purpose acted, only indirectly, through powerful coil machines or local relay batteries.

It remains to consider some of the imperfections which attend the electric telegraph, and considerably limit its useful applications. When it was first suggested as a substitute for the optical telegraph, which was useless in dark nights and in fogs or snow-storms, it was confidently anticipated that the system of electric signals would be available in all states of the weather. But this expectation has proved fallacious. For hours together the telegraph will not work. This failure is sometimes owing to the insulation of the wires along the poles having for the time been destroyed by moisture. The porcelain insulators, however, are now made of such a shape, and are so well protected from rain by sloping covers, that non-insulation from moisture occurs much more rarely than might be expected. There are certain damp fogs, nevertheless, or mists, which penetrate every where; and so thoroughly wet the porcelain tubes, that they become conductors of electricity. In those circumstances it travels from the battery no further than the first wet post, down which it passes to the earth, and returns to the battery.

But a much more troublesome cause of inaction, or of irregular action in telegraphs, is the influence of atmospheric electricity upon them. The door left open that the friend may enter, stands open also for the foe. The insulated wires stretched along the telegraph posts for hundreds of miles, in order that a special current of electricity evolved by a battery shall travel only in one direction, cannot, like a private road, be barred against electricity evolved from other sources. Nor is this all. When the electrician wishes to collect atmospheric electricity, he insulates a metallic wire, and suspends it in the air. In other words, he acts exactly as the constructor of the telegraph does, though with a very different object in view. The latter, much against his will, finds that his wires not only permit, but invite atmospheric electricity to employ

them as a highway. They act, in short, as lightning conductors; and lead the formidable meteor into every station, where it deranges or destroys the coils and magnets, and occasionally menaces buildings, and even life, with destruction.

To guard against these serious evils, lightning-rods, descending to the ground, are fixed at intervals to the telegraph-posts, and at the station-houses. The sharp spikes in which these rods terminate above, being elevated considerably beyond the telegraph-wires, present points of attraction to the electricity of the clouds, so that it is determined to them rather than to the less exalted and unprojecting wires. It is thus transferred from the atmosphere to the earth without affecting the telegraph. The rods in question, however, only protect the wires in their immediate neighbourhood, and that ineffectually.

An additional and more effectual mode of protection is to place a knob of metal on each wire where it crosses the posts. A second and lower knob is then placed close to the first, but without touching it, and connected with a wire led down the post to the ground. If the lightning discharge ran along the wire, it would be cut off at the first knob it reached on the line, on reaching which it would leap across to the lower knob, and descend to the ground; while the current from the battery is found not to have sufficient intensity to overleap the space between the knobs, and hence does not descend the wire, as it would do if the knobs touched. But it may overleap in rain.

An additional and very ingenious device against lightning-shocks injuring the station-houses, consists in making one part of the wire which is led off to them from the main line very thin. If a powerful electrical discharge reach this, it melts it; so that the lightning, like an enemy too hasty in pursuit, burns the only bridge by which it could cross to make an attack, and remains on the safe side,—out-generalled by itself.

By one or other, or all of the methods described, sufficient protection can, on the whole, be secured, against the more fami-

liar and more perilous effects of atmospheric electricity. Electrical disturbances, however, of a kind which do not manifest themselves in discharges of lightning, or involve life or ordinary property in danger, are quite sufficient to affect the operations of the telegraph. During snow and hail-storms, whilst dry fogs are prevailing, when the aurora borealis appears, and in truth during most meteorological changes, much electricity is developed in the atmosphere. It is sometimes directly transferred to the telegraph-wires, but as frequently its action is only indirect. A body in which free electricity is in any way developed determines a similar electrical condition in an insulated mass of metal near it, exactly as a magnet induces magnetism in pieces of iron placed in its neighbourhood. Thus an electrical cloud floating along above the extended wires generates a current of electricity in them; or, to speak more strictly, causes the electricity naturally present in a latent state in the wire, to become free and move along the metal. The currents which thus travel, as well as those which are directly transferred from the atmosphere, have the same effects on the index-needles and signal-bells, as the electricity purposely sent along the wires from the battery. The needles are swung unceasingly to and fro, or remain for hours deflected to one side. The bells ring violently at irregular intervals, or stop only when their weights are run down. Signals cannot be transmitted at all when atmospheric electricity is thus largely developed; and they become more or less confused whenever it is sufficiently powerful to affect the index-needles.

Apart altogether from its practical importance, there is something exciting in the contemplation of these strange atmospheric influences. It must be not a little startling to the drowsy occupant of some solitary telegraph station, to be roused from his midnight slumber by the spectral clanging of his signal-bell, bidding him quail at the wild quiverings of the magnets, swayed plainly by no mortal hands. An imaginative man

might then recall the legends which tell of disembodied souls sent back to this earth, to divulge some great secret of the world of spirits, and seeking in vain for means of utterance, which shall be intelligible to those in the body. A philosopher, too, might accept and interpret the legend. For it is sober truth, that the apparently aimless and meaningless movements of the magnetic needles when vibrating at such times, are, after all, the expressive finger-signs of a dumb alphabet, in which nature is explaining to us certain of her mysteries; and already, too, we are learning something of their significance.

Peculiar difficulties have attended the transmission of electric signals through some of the railway tunnels. Those have been traced in most cases to the effect of moisture or of the engine smoke in destroying insulation; and the wires have in consequence been coated, like those of the marine telegraph, with gutta percha.

In other cases the index-needles at the stations nearest the tunnels have remained set to one side for considerable periods. This has been referred to the influence on the tunnel wires of electrical or magnetic disturbances in the strata in the neighbourhood of the tunnel. If this view be well-founded, it would be wise to make the telegraph-wires, where they pass through the tunnels, of copper, and not of iron, as the non-magnetic character of the former metal makes it less susceptible of electrical excitement. A wire cannot be magnetic and electrical in the same direction at the same time. If a telegraph-wire become magnetic in the direction of its length, like a long compass-needle, it will resist the passage of comparatively feeble electric currents, which would have traversed it had it been non-magnetic. This fact has not, perhaps, been sufficiently considered in the explanations which have been given of the derangements of the telegraph. Iron becomes so readily magnetic, that the telegraph-wires, when made, as they generally are, of that metal, cannot in certain circumstances escape being

magnetised by the earth. Now that railways are projected in India, it may not be amiss also to notice that near the Equator iron rods or wires lying north and south after a time become magnetic. And wherever, in other regions, the wires are extended in the direction of the magnetic dip, the same effect will occur. The cheapness, elasticity, and strength of iron, however, more than counterbalance the inconveniences under notice.

Many of the evils referred to are avoided in the underground telegraph, which is largely employed on the Continent. In it the wires, which are of copper, are not stretched along posts, but covered with gutta percha and buried at some little depth in the ground. Snow-storms, heavy rains, and fogs do not destroy the insulation of the wires, as they do that of those suspended in the air; nor are the subterranean wires deranged by atmospheric electricity, or subject to the influence of thunder-storms. But it does not appear that they are indifferent to the disturbing effect of the aurora borealis, which often interferes with the working of the aërial telegraph; and it may be suspected that alterations in the intensity of the earth's magnetism, which we know are constantly occurring, will affect the buried much more than the suspended wires.

In favour of the subterranean telegraph, it is alleged that, though at first more costly, in the end it is much cheaper than the aërial one, as the posts which the latter demands require renewal at intervals, and the suspended wires, in consequence of their exposure to great variations of temperature, and the vibrations determined in them by the impulse of the wind, the passage of railway trains, and the transmission of electric currents, undergo a change in structure, and become so brittle as readily to snap across. On the English railways, however, such brittleness as the Prussian engineers refer to has not been observed to occur in the suspended wires, although it is not to be denied that both in the aërial and subterranean telegraphs the wires slowly undergo a molecular change, which

will alter their power to convey electricity; and that the aërial arrangement is exposed to more disturbing agencies than the subterranean one.

On the other hand, it is acknowledged that it is more difficult to secure the insulation of the buried wires, and where this is defective it necessitates the employment of more powerful batteries to force the current along the imperfect conductors. Further; the buried wires are with difficulty reached when deranged, and each wire laid down requires an insulating cover to itself, whereas in the aërial telegraph one post will carry any number of wires. The encasing of the wires also in gutta percha determines certain electrical conditions similar to those of a Leyden jar, which do not occur in the suspended wires, and which interferes with the action of the embedded wires as transmitters of electricity.

The subterranean telegraph has only been in use since 1848, so that its peculiarities and defects are less known than the aërial one, which has been at work since 1838. A further period, accordingly, must elapse before we can decide which is the preferable arrangement. Had gutta percha been as well known in 1838 as it was ten years later, subterranean telegraphs would long ago have been constructed in England, where they were abandoned from the difficulty experienced in finding a suitable and sufficient insulating substance with which to cover the buried wires. Subterranean telegraphs, or rather sets of telegraph-wires, now extend through a large area of Great Britain and Ireland, so that we are able to contrast the working of the two methods at present in vogue; and we cannot but rejoice that different methods of arranging the wires were adopted on the Continent and in England, as we had thus a comparative trial on the largest scale of the two methods, which doubled within a given period our experience in the working of telegraphs, besides throwing much light on the electrical dis-

turbances which occur in the atmosphere and within the earth.

We have said nothing regarding the history of the electric telegraph which cannot yet be written otherwise than in the faintest outline. Its earliest scientific originators were Oersted, Ampere, and Wheatstone. Its chief practical constructors have been Wheatstone and Cooke in England, to whose merits we need not again refer; in Scotland, Bain, a man of great inventive skill and ingenuity; in America, Morse, another distinguished mechanical genius; and on the Continent, Siemens of Berlin, the deviser of the Prussian subterranean telegraph. Lastly, we make special mention of Brett and Crampton, who have achieved the construction of the first transmarine telegraph. It must be left to the survivors of those ingenious men, and of the many others who by discoveries in science or practical trials have made the telegraph what it is, to adjust their great but various merits. They are most of them still in life, and few of them past their prime, so that before they become subjects of history, they will have added, as at brief intervals they are doing, to the perfection of the instrument with which their names are connected.

Meanwhile, if our electric telegraph is not perfect, as no tool of man's is, it assuredly is a most wonderful instrument: and it has been brought from small beginnings to its present completeness in a singularly short period of time. To unscientific observers, indeed, the rapidity of its development cannot, we think, but seem miraculous. Like some swift-growing tropical plant, it has spread in a few months its far stretching iron tendrils throughout the length and breadth of the land. It would have done so, however, twenty years ago, had the mechanical conditions for its extension existed: and we must thank the railroads for its early maturity. Till they provided a secure pathway for its progress it could only exist in embryo. It now fringes every railway with its harp-like wires, — apparently as inseparable and as natural an appendage

as the graceful parasitical orchideæ which spread along the South American forest trees.

Nursling, however, as the electric telegraph is of this century, almost of this decade, an ingenious pupil of Niebuhr might find in an ancient tradition its birth foretold centuries ago. In the year 1517, as the historians of the Reformation tell us, the Elector Frederick of Saxony had a strange dream. The monk Luther appeared to him, writing upon the door of the palace-chapel at Wittemberg in his dominions. The pen which Luther handled was so long that its feather-end reached to Rome, and shook the Pope's triple crown on his head. The cardinals and princes of the empire ran up hastily to support the tiara, and one after another tried in vain to break the pen. It crackled, however, as if it had been made of iron, and would not break; and whilst they were wondering at its strength, a loud cry arose, "and from the monk's long pen issued a host of other pens."

The Elector's dream, has been fulfilled in our own day. The long pen of iron sprouting forth hosts of pens is in our hands; and every day grows longer. It *has* reached to Rome, and much further; it has shaken popes and kings, and emperors' crowns; and foretold, like the pen which Belshazzar saw, the fall of thrones and the ruin of dynasties. It has written much of wars and revolutions, and garments rolled in blood; and must write much more. But it is the emblem and minister of peace—and the Long Pen shall yet vanquish the Long Sword.

There are other relations, however, than those we have yet referred to, in which the telegraph is daily becoming a more and more important instrument. Hitherto we have referred solely to its application to the practical *reduction* or *annihilation* of TIME; we have now to consider the beautiful way in which it can be made to *measure* it, which has already attained such perfection, that it would be quite possible to make every series of telegraph-wires form part of a gigantic system of clockwork,

by means of which, time-pieces, separated from each other by hundreds of miles, may be made to keep exactly equal time, and the clocks of a whole continent move, beat for beat, together. In short, our electric telegraphs might now have the additional duty imposed upon them of acting also as essential parts of electric clocks. We proceed to consider how this could be effected.

As electricity generated at one point, can be employed to move magnetic needles at a great distance, so it may be made to move the hands of a clock or time-piece; but to achieve the movements requisite in an accurate timekeeper, will plainly be a much more difficult task than to deflect magnets, which, provided only they point to either side when required, need not do so at equal intervals of time. We must first then inquire, how it is possible to apply electricity to move clock-machinery, and thereafter we shall see to how many important purposes electric clocks can be applied.

An ordinary clock consists essentially of a series of wheels acting on each other, and carrying round, as they revolve, the hands which mark the seconds, minutes, and hours. The wheels are moved by the falling of a weight, or the unwinding of a spring, and the rate at which they revolve is determined by the length of a pendulum made to oscillate by the wheels. In electric, or (as they should rather be called) electro-magnetic clocks, there are neither weights nor springs, so that they never run down, and never require to be wound up. To produce motion, electricity is employed alternately to make and unmake an electro-magnet, or alternately to reverse the poles of a permanent magnet, which, by lifting up and letting fall, or attracting and repelling a lever, moves the wheels.

In Mr. Bain's simple and very beautiful clock, the pendulum itself is the lever moved. The bob of the pendulum is a large brass bobbin like those used for holding thread, on which a long copper wire, covered with silk, is coiled, and

connected at either extremity with the zinc and copper of a voltaic pair. In the clock-case, on either side, are permanent bar-magnets, which project with opposite poles from the case, into the hollow axis of the bobbin. When a current of electricity is sent along the wire, the bobbin becomes an electro-magnet; and being attracted by the one permanent magnet, and repelled by the other, moves to the one side, where it would remain if the current continued to circulate. The wires, however, are so arranged, that when the pendulum is thus pulled to one side, it makes a break in one part of the covered wire, and thereby cuts off the current. The bobbin, in con-

Fig. 8.

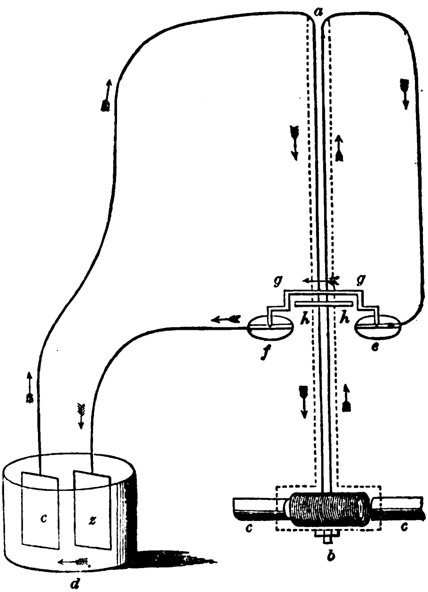


Fig. 8. skeleton diagram of Bain's pendulum.

a, pendulum drawn in dotted outline.

b, bob of pendulum consisting of a hollow cylindrical brass box, containing a lengthened coil of covered copper wire surrounding a bobbin.

c c, two permanent bar-magnets projecting from opposite sides of clock-case into centre of cylindrical pendulum-bob. They are drawn a little shorter than they should be, to show their free extremities, which are oppositely magnetic, the one being a north, the other a south pole.

d, voltaic pair: the arrows show the direction of the current. A wire from the copper is conducted to the top of the pendulum-rod, then down its left hand side to the bob, in which it is coiled many times, and then ascend-

sequence, ceases to be an electro-magnet, and falls back by its own weight. In so doing, it fills up the break in the covered wire, allows the electricity again to pass, which a second time renders the bobbin magnetic, and determines its motion by the permanent magnets in the clock-case. The pendulum is thus made to oscillate in the one direction by gravity, and in the other by the action of permanent magnets on a temporary magnet; and so long as the current of electricity continues to flow, the pendulum will keep swinging, alternately cutting off and letting on electricity, and making or unmaking the bobbin-coil a magnet, as it oscillates to the left or to the right. The drawing, *Fig* 8., illustrates its mode of action.

A pendulum, such as this, can readily be made to communicate motion to clock-wheels, of which it is at once the mover and the regulator, and it may be at any distance from the battery which furnishes the electric current. A clock in

---

ing on the right side to the top of the pendulum-rod, it is brought down within the clock-case and terminates in a disc *e*, made of grooved agate. The black dot in the groove represents a gold stud which forms the termination of the wire from the copper. *f* is a second grooved disc, made, however, entirely of metal, from which a wire proceeds to the zinc. The current thus can only pass, if a metallic bridge stretches from the disc *f* to the gold stud in the disc *e*. This bridge *g g* stands in the grooves on the two discs, the left extremity sliding in the metal, the right extremity in the agate. *h h* is a piece of brass attached to the pendulum-rod, so as to touch the bridge and carry it from side to side. In the diagram the apparatus is not acting. Suppose, however, that the right hand extremity of the bridge touch the gold stud in the agate disc, then the current passes, the coil of wire in the pendulum-bob becomes magnetic, and is carried to the *left* by the action of the bar-magnets. In so doing it slides the bridge off the gold stud, and thereby cuts off the current from itself, and loses magnetism. It returns to the *right* by its own weight, but in so doing it replaces the right end of the bridge on the gold stud, and thus restores the current to the wire and renews its magnetism; and so on *ad infinitum*. Strictly speaking, the edges only of the discs should be shown; they are represented as if seen a little obliquely from above, for the sake of indicating the grooves more distinctly.

London might thus be moved by a battery in Edinburgh, if the telegraph wires were made to convey the current. No particular advantage would result from such an arrangement. If, however, a clock moved by weights, or a spring, and constructed with great nicety so as to keep accurate time, were situated in the astronomical observatory at Edinburgh, it could be made to control one of Mr. Bain's clocks in London in the following way. Let a voltaic pair be placed in the Edinburgh observatory, with wires communicating with those of the telegraph, and let the pendulum in London connected with the telegraph-wires, be constructed in the mode already described, but without any break in the wire, which the oscillations of the *London* pendulum should at intervals fill up. With such an arrangement, the pendulum would make a single vibration, and remain pulled to one side so long as the current passed. It would be easy, however, for a person at Edinburgh to interrupt and renew the current at intervals, and thus make the distant pendulum vibrate at whatever rate he chose; and by arranging one of the wires so that the oscillations of the pendulum of the Edinburgh observatory clock should alternately make a break in it, and fill that up, the London pendulum might be kept oscillating at exactly the same rate as the Edinburgh one, provided the current of electricity did not vary in intensity. Nor would one distant pendulum be all that could thus be kept moving; provided a sufficiently powerful battery were employed at Edinburgh, any number of pendulums might be connected with the telegraph wires at the stations or elsewhere, all of which would keep equal time, and follow the oscillations of the Edinburgh pendulum. In this way a single costly and carefully constructed astronomical clock, worth many pounds, would transfer its own accurate movements to a countless number of pendulums, which, even when connected with clockwork, might have their value estimated in shillings; and wherever we chose to stretch the

telegraph-wires throughout the length and breadth of the land, we could set up a clock and read on its face the evidence of the care which the far distant astronomer bestowed on his observatory clock. We are indebted to Wheatstone for the first suggestion of such a scheme, but we have described it in connexion with Bain's pendulum, and it will be manifest that the whole clocks of a town could thus be kept moving beat for beat, and keeping equal time, instead of each keeping a lawless time of its own, as is customary with the clocks of most towns at the present period: nevertheless, electric wires are costly things.

In the description just given, we have selected the simplest electro-magnetic clock as the one most easily followed, and have assumed that it is possible to send along a telegraph line a current of electricity of unvarying intensity. Unfortunately, however, it is impossible to do this. Even the so-called constant batteries supply currents too variable in intensity to be applicable to so delicate a matter as the exact measurement of time; and although the battery were perfect, the arrangement would still be at fault. We have already seen how great the disturbing influence of atmospheric electricity is on the currents traversing the telegraph-wires; and the clock would still be more sensitive to such disturbances than the indicating needles of the telegraph dials are. Mr. Bain's beautiful arrangement, accordingly, would not furnish the means of keeping unvarying time. Within the last three years, however, another electro-magnetic clock has been constructed, which is already in use along one of the telegraph lines, and is likely to be extensively employed. It is the device of Mr. Charles Shepherd, and was shown in action at the Great Exhibition, moving the hands on the immense and singular semicircular dial which was constructed on the south front of the arch of the transept. It includes three separate electro-magnetic arrangements with distinct batteries; the first to move the pendulum, the second to move the wheels, and the third to strike the

hours. The pendulum is entirely disconnected from the wheels. It is neither moved by them, as in ordinary clocks, nor communicates motion to them, as in Bain's clock. Nevertheless, it controls the motion of the wheels by determining at what intervals the electricity which moves them is cut off and let on to them. The bell stroke is regulated by the wheels, and also by the pendulum, but has a battery for itself. It will not be necessary, however, to refer minutely to the arrangement for striking the hours.

The pendulum is kept in motion by *four* forces, two of which act *directly*, viz. elasticity and gravity; and two *indirectly*, viz. electricity and magnetism. The action of the direct forces is as follows:—A bent spring let loose in one direction throws the pendulum to one side, and the pendulum returns by its own gravity. Whilst it is returning the spring is re-bent, and held back by a detent or catch, which the pendulum itself raises when near the limit of the oscillation which gravity determines, so as to receive from the spring a second impulse to the opposite side. It will thus be understood that some arrangement must be provided for re-bending and holding back the spring, till the pendulum again acquires an impulse from it. This re-bending of the impulse-spring is determined by an electro-magnet, to which a current of electricity is alternately allowed to pass, and then cut off, as the pendulum moves to one side or the other. The pendulum is in permanent connection with one pole of a battery. A wire from the other pole is touched by the pendulum-rod as it moves to the one side so that the current passes, and is separated from it when it swings to the opposite side, so as to cut off the current. When the current is on, it throws into action the electro-magnet, which pulls down an armature or keeper, and this acting on a compound lever, locks back or re-bends the impulse spring, so that it is caught by the catch or detent. When the current is off, the electro-magnet becomes inactive, and a

counter-balancing weight and spring raises the armature from the electro-magnet, so as to be ready to act again, and re-bend the spring when the current is restored. The electro-magnetic arrangement is thus solely employed to re-bend the spring, and it does not matter how much the electricity, or the magnetism which it induces, varies in intensity, provided they are sufficient to re-bend the spring at every alternate oscillation. The release of the spring is effected by the direct mechanical contact of a small arm or point projecting from the pendulum-rod. The diagrams, *Figs.* 9. and 10., will illustrate the action of the clock.

The peculiar advantage of the arrangement just described is that

Fig. 9.

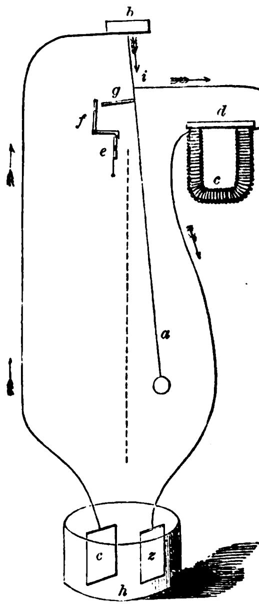


Fig. 9. Skeleton Diagram of Shepherd's Pendulum.

a, pendulum which has completed oscillation to right, and is about to return by its own weight.

b, portion of brass framework of clock from which pendulum is suspended.

c, horse-shoe electro-magnet, which, by attracting keeper or armature *d*, moves the levers (not represented in the drawing), which lock back the impulse spring *e*.

e, impulse-spring held back by catch or detent *f*.

g, projecting point on pendulum-rod, which, when pendulum swings to the left, throws the detent to the same side, and allows the impulse-spring to fall to the right, and carry the pendulum in the same direction.

h, voltaic pair. The current, as indicated by the arrows, flows from the zinc to the copper up to the clock-frame, then down the pendulum rod to the point *i*, from which, when the pendulum is at the extreme right (as in the diagram), it passes to the second wire round the electro-magnet and

no increase in the intensity of the electrical currents employed in moving the machinery affects the rate at which it moves. The only mode in which the electricity can be rendered ineffective is by reduction of its intensity, which by due management of the batteries may, without difficulty, be prevented occurring; or by obstacles to its passage along the wires, which, we have already seen, may be occasioned by atmospheric or terrestrial disturbances. But the influence of these on Shepherd's clock will be much less than on Bain's, or on the ordinary indicating needles of the telegraph box, inasmuch as in the first arrangement the electrical currents do not act *directly* on the moving parts, as they do

Fig. 10.

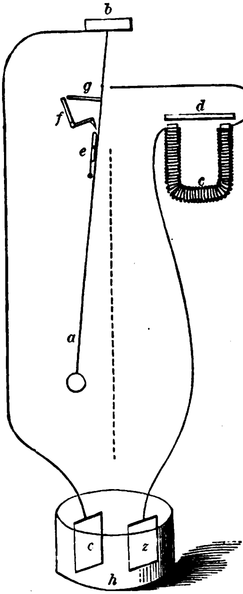


Fig. 10. Skeleton Diagram of Shepherd's Pendulum.

---

back to the zinc. The current, it will thus appear, only flows, and the electro-magnet is only in action, when the pendulum is at the extreme right. The dotted line represents the vertical position of the pendulum when at rest.

Fig. 10.—*a*, pendulum which has completed oscillation to left, and is about to pass to the right from impulse of spring.

b, clock-frame to which pendulum is attached.

c, electro-magnet *not* in action.

d, keeper or armature raised by levers and counter-balancing spring and weight (not shown in drawing).

e, impulse-spring set free, and pushing pendulum-rod to the right.

f, detent pushed to the left so as to liberate *e*.

g, projecting point on pendulum which acts upon detent *f*, and releases impulse-spring *e*.

h, voltaic pair. The current not passing. The dotted line represents the vertical position of the pendulum when at rest.

in the second two arrangements, so that if the clock goes at all it will keep accurate time.

A large Shepherd's clock is now in construction at Greenwich Observatory. By means of the submarine telegraph wires it can communicate with Paris and with the entire continent; by means of the various railway lines it can communicate with all the great towns of this country; and we may thus receive Greenwich time literally from Greenwich, and set our watches by the dial at a railway terminus with as much confidence as if we were gazing on the face of one of the exquisitely constructed clocks which the Astronomer Royal regulates with so much care.

How this is to be effected will be understood by the following account communicated to the "Times" newspaper by Mr. Charles V. Walker, the accomplished telegraph engineer on the South-Eastern line.

"Wires are to be laid underground from the Royal Observatory to the Lewisham station by the electric telegraph company. From the London station wires will diverge to Westminster, to the Royal Exchange, and to the central telegraph station at Lothbury.

"The objects the promoters have at present in view are —

"1. To transmit Greenwich time and corrected time to and from the clock at the New Houses of Parliament and the Royal Exchange.

"2. To transmit Greenwich time throughout the kingdom by the various lines of electric telegraph.

"3. To compare the transits of stars at Greenwich with the same at Paris.

"The transmission of time-signals will be automatic. Shepherd's electric clocks will be placed in the Royal Observatory in conjunction with an automatic apparatus to be appended to the clocks at the various stations. With respect to the signal to the New Houses of Parliament, a certain time will be agreed

upon, and the adjustment at Greenwich will be made accordingly. There will be a permanent electric circuit maintained between Westminster and Greenwich, broken only at the clock at Greenwich and in three places: one of these breaks is completed every minute, one every hour, and one every twenty-four hours, at the time agreed upon; and as these three contacts will occur simultaneously only once a-day, at the precise hour, minute, and second determined upon, the signal which then passes will be the true time required, and it will be made accurate to the 1-20th of a second. In the first instance this signal will be made manifest at Westminster by the motion of a needle. The pendulum there will be furnished with two oscillating bars, one for 'too fast,' and the other for 'too slow,' and either this or that may be made to act on the pendulum by the clock inspector as the case may require, and for a certain short time. At the end of half an hour the Westminster clock will automatically send its time to Greenwich to be observed and recorded.

"To distribute time throughout the kingdom, the clock at the London terminus of the South-Eastern railway will be provided with special wheels and studs. A certain hour will be determined on for transmitting time to Dover for example; and about fifty or sixty seconds before this time the London clock will disconnect the Dover telegraph wire from the telegraph instrument at London, and will place it in connexion with the wire that leads to Greenwich. Precisely at the last second of the minute, the Greenwich clock will place this same wire in connexion with the voltaic batteries of the Royal Observatory, and a signal will be visible at Dover and at all other stations on the same wire. The Greenwich contact will be instantaneous, but that at London will remain a few seconds longer, always allowing a margin for the variation of the ordinary clocks. As the Greenwich wire is taken off the Dover wire, it will be placed in contact, automatically, with the Lothbury

wire, where a clock may be fitted with contacts corresponding to such lines of railway, and such towns or stations as may require time-signals."

It remains only to notice the beautiful applications of electro-telegraphic arrangements to astronomical observations, which were first put in practice by the American professors, and are now about to be employed by the British and French astronomers. These are the mechanical registering of the instants at which astronomical phenomena occur, and the transmission of time-signals from one station to another. It will conduce to perspicuity if the subject is considered under three divisions; namely, 1. The application of electro-magnetic apparatus, *without the intervention* of the telegraph wires, to the observation of astronomical phenomena at a single observatory. 2. The application of electro-magnetic apparatus, *with the assistance* of the telegraph-wires, to the transmission of time-signals, or records of the occurrence of astronomical phenomena from one station to another. 3. The application of the combined apparatus to the determination of differences in longitude.

Observations of the times at which astronomical phenomena occur are necessarily difficult, for the astronomer must at the same time do two apparently incompatible things; namely, observe the motion of a star, and that of the hands of a clock. As he cannot gaze at both, he turns his *eyes* from the clock to the telescope a few seconds before the transit (as it is technically called) of the star occurs, and then transferring to the *ear* the charge of the clock, counts its beats till the transit happens, when he notes the time. Such an association, however, of the eye and ear as is thus required, is at best imperfect, and throws a great strain on the attention of the observer, so that the results are less accurate than they might be. By the ingenious devices of the American astronomers, especially Bond and Locke, an electro-magnetic apparatus was so arranged, that when the current of a battery passed along a wire

and called into action an electro-magnet, the latter pressed down a steel point or pen on a ribbon of paper, and made a permanent mark on it. A piece of ordinary clock-work was made slowly to unwind the ribbon of paper from a cylinder or roller, so that different points upon its surface were successively presented to what we may call the electro-magnetic *pen*. By arrangements the same in principle as those adopted in Bain's and Shepherd's clocks, the pendulum of an astronomical clock is made to let on the current to the *pen* once every second, so that at each second a mark is made on the paper ribbon. In this way the clock permanently marks its own beats, and the observer, turning a deaf ear to its clicking, can gaze with undivided attention on the motion of the star across the field of his telescope. Let us suppose, for simplicity's sake, that this passage or transit of the star occurs exactly at a second as indicated by the clock-beat, then this second will be marked upon the unwinding ribbon; and if it have been previously divided into spaces corresponding to hours and minutes along its length; or if any one second-mark on the ribbon be noted from the clock, for example, exactly at the stroke of an hour, so that we may reckon along the ribbon from this, then by mere inspection we shall observe and may mark the instant of the occurrence of the transit. To do this, we may suppose the astronomer to withdraw his eye from the telescope the moment the transit occurs, and to put a pencil mark opposite the last impression which the electro-magnetic pen has made. It soon occurred to the observers, however, that this record might also be made by electricity. For this purpose it was only necessary to have a second electro-magnetic apparatus moving a pen, and so arranged that the observer could at will, by touching a finger-key, call the apparatus into action by allowing a current to flow from a battery. If we suppose this additional pen placed at the side of the one already described, so that it mark the same ribbon, then the object in view will be secured. To prevent confusion,

let the one arrangement be styled the *clock-pen*, and the other the *star-pen*. The former is making a mark every second near the *right* edge of the ribbon, while the *left* edge is free to receive the marks of the latter. The moment the transit of the star occurs, the observer, *without withdrawing his eye*, touches a finger-key, and instantly the star-pen makes its mark, side by side with one of the marks of the clock-pen; the transit, for simplicity's sake, being supposed never to occur at the interval between two seconds. If, however, it should occur at such intervals, it is easy, by dividing the space between two second marks into equal portions, to register the transit to the tenth or other fraction of a second. By such arrangements, it will be seen that rapidly succeeding phenomena, such as those which characterise an eclipse, may be unerringly noted, without the observer ever needing to shift his eye from his instrument, or to do more than merely touch a key with his finger.

We are now to inquire, in the second place, how such observations can not only be accurately, permanently, and instantaneously recorded at the spot where they are made, but with equal accuracy, permanence, and rapidity, at a distant station. Let us imagine, for example, that the Astronomer Royal at Greenwich engages to communicate to the Director of the Observatory at Paris the instant when the total phase of a solar eclipse is observed to occur at the former locality. It would be quite sufficient for this purpose that the ordinary apparatus of the telegraph, described in the early part of this sketch, was employed; so that by means of the wires stretching from Greenwich to Paris, the English astronomer could at will produce a signal such as the deflection of a magnetic needle at Paris. The apparatus just described, however, would be still better. Let the Parisian Observatory be provided with such a time-ribbon and clock-pen as we have already described, under the control of the local director. In

addition, let the star-pen be so arranged, in connection with the telegraph wires, that it can be actuated by a current sent along them, and let any marks be agreed upon to represent intervals of time, and it will be easy for the English observer to mark upon the Paris ribbon the *time* when an event occurs at Greenwich, by touching a finger-key which transmits a current. The mark may be made on the same or on a different ribbon from that impressed by the Parisian clock-pen, and it will constitute a *time-signal*, as it is called. Such time-signals may be made in many ways, and for many purposes. The most manifest one is the rating of clocks and chronometers; but a not less interesting one is the determination of longitude. To render intelligible this part of our subject, we must enter into some brief detail in reference to the mode in which longitude is ascertained. We are indebted to an astronomical friend for the following account of the matter:—The determination of the longitude of a station by astronomical observations, is founded on principles which will be apparent from the following illustration. To take a simple case, suppose a spectator situated on the equator, and that a particular star is directly over his head, so as to be seen through a telescope fixed vertically. Immediately, owing to the earth's rotation, the telescope will turn away from the star, which will no longer be seen in the middle of the field of view, and will in a short time move out of it altogether. The spectator must then wait until the earth has made a complete revolution, or until twenty-four hours of sidereal time have elapsed, before he can again see the star in the middle of the field; owing to the earth's rotation having brought the telescope back to its original position. In this way he will see successive *transits* of the star across the field of his telescope at intervals of twenty-four hours. Suppose, next, two observers placed at *opposite* points of the earth's equator, and therefore at stations whose longitude differs by 180 degrees, each in his turn will witness a transit

of the star over his head after an interval of twelve hours; and, in like manner, four spectators placed at equal distances from each other on the equator, will in succession see the star pass through their telescopes after intervals of six hours. It is thus evident that differences of 360, 180, and 90 degrees in the longitudes of stations will cause differences of twenty-four hours, twelve hours, and six hours in the observed times of transit of a star; supposing the observers to be all furnished with watches indicating identically the same time. The difference of longitude of two stations will thus be found, provided we know the interval between the times at which a star has crossed the meridians of the two stations; and as a difference of 360 degrees of longitude corresponds to twenty-four hours, one hour of difference in the times will indicate fifteen degrees of difference in the longitudes.

We have supposed the observers' watches all to indicate the *same* time, a condition which cannot be fulfilled in practice; but it is not necessary that it should, for if we know the errors and rates of the watches, we can apply such corrections as to reduce the indications to what they would have been, on the supposition that each watch indicated the same time. It has also been assumed that all the watches were regulated to the same time, and then the differences of the observed times of transit of the star would give the difference of longitudes of the stations. The difference of the longitudes would, however, be equally well obtained if each watch was regulated so as to indicate the *same* time when the transit of the star was observed. The watches would now no longer indicate the *same time if compared;* but the *differences* in their indications when they were compared would give the differences of the longitudes of the stations from which they had been brought, at the rate of fifteen degrees of longitude to one hour of difference in the indicated time.

It has been supposed that all the watches have kept correct

time, or, what comes to the same thing, that their errors have been known at every instant, so as to admit of being applied as a correction to their indications. But as the most perfect chronometers are apt to vary in their *rates*, it is obvious that the method of determining the longitude which has just been described must be liable to errors; and those errors will accumulate in proportion to the length of time that elapses after the observations of the star, before the watches are compared. Almost all error, however, could be avoided in one of two ways: the first being to afford the observer at one station the means of sending instantaneously intelligence of the time indicated by his clock to the other station, so as to compare the times at the two stations at any instant that may be desired; and the second being to send, in like manner, intelligence of the moment at which a star is seen to cross the meridian of the station.

Thus, in the case of two stations, according to the first of these methods, we shall suppose that a certain star passes through the transit telescope at one o'clock of *local* time at each station; the one observer, after witnessing the transit, transmits intelligence instantaneously to the other that his clock indicates 1 hour 15 minutes; but at this instant the latter finds that his clock is indicating 1 hour 3 minutes. There is thus found to be a difference of 12 minutes in the local time of the two stations, or 3 degrees of difference in their longitudes.

Following the second method, the one observer would transmit instantaneously the intelligence of the transit of the star, while the other watched his clock and noted the time, which we shall suppose was 1 hour 3 minutes; but the latter has to wait until 1 hour 15 minutes before he witnesses the transit of the star, which has thus been 12 minutes later in arriving at the meridian of the latter station. The difference of longitude is thus found, as before, to be 3 degrees.

Now as the apparatus of the electro-magnetic telegraph which has been described, affords the means not only of transmitting instantaneously, signals of time indicated by the clocks, or of the instants when astronomical phenomena occur, but also of noting those times mechanically, it is obvious that such arrangements may be employed for the purpose of ascertaining differences of longitude with the utmost precision.

How high a value, indeed, is set upon the electro-telegraphic method of ascertaining longitudes, may be gathered from the following statement of Sir John Herschel: —

"Whatever means can be devised of exciting in two distant observers the same sensation, whether of sound, light, or visible motion, at *precisely the same instant of time*, may be employed as a longitude signal. Wherever, for instance, an unbroken line of electro-telegraphic connection has been, or hereafter may be, established, the means exist of making as complete a comparison of clocks or watches as if they stood side by side, so that no method more complete for the determination of differences of longitude can be desired. The differences of longitude between the observatories of New York, Washington, and Philadelphia, have been very recently determined in this manner by the astronomers at those observatories."

To how many other uses the telegraph wires will be applied, we can only as yet surmise. They will very soon be employed in our own country to drop Time-balls like that at Greenwich, so as to furnish our ship-masters with the means of rating their chronometers. In Germany they have been stretched from the central police stations in certain of the large towns to each of the subsidiary offices, so that the announcement of a crime may be instantly, as it were, made to reverberate through the city, and every officer of justice be on the alert for his prey. In America it has been proposed to have the whole church bells of a district arranged so that, in the event of a fire, one electric current might set them all simultaneously ringing; and the

Sunday chimes might readily be rung by the same agency. We need not particularise further. In England we are apt to think of the telegraph as inseparable from the railway. On the Continent and in America it is in action in many places where the railway is unknown.

Wherever, in truth, wires can be stretched, whether suspended in the air, or buried in the earth, or sunk in the sea, there our wonder-working apparatus may be erected. A few square inches of zinc and copper will produce for us a force which, on the other side of a continent or an ocean, will speak for us, write for us, print for us, keep time for us, watch stars for us, and move all kinds of machinery. No distance will stop its march; for where the force of one battery is spent, it can be made to call into action another or *relay* battery, which will carry on the message, so that if the wires were laid it might sweep round the globe. Such a network of wires, we may hope, will one day connect together the ends of the earth; and, like the great nerves of the human body, unite in living sympathy all the far-scattered children of men.

We closed the last issue of this work with the expression of a hope, that the telegraph wires which form, as it were, the nerves of the great globe, might spread their beneficent network over the world; much more has been done in the interval towards realising this desire, than in our most sanguine mood we had ventured to anticipate. War, no less than peace, has multiplied the ramifications of the telegraph, and Great Britain has in the one direction reached almost to India; and, in the other, has touched with electric finger the shores of the New World, and sent greetings across the sea from Nova Scotia to New Orleans. A glance at a telegraphic map ten years old and at one just issued, will show to how vast an extent the four

quarters of the globe have been traversed by the telegraph within that brief interval. In Europe alone, we count some 55,000 miles of telegraph lines, the great majority of which include many wires. In America there are some 45,000; and if we add to these the 2000 odd miles of the Atlantic cable, we have altogether some hundred thousand miles of wire uniting the ends of the earth together.

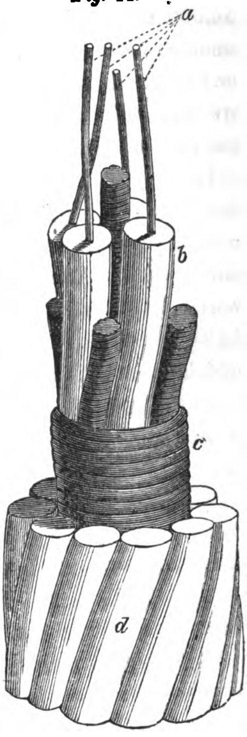
Of those extensions of the telegraph the most remarkable are the submarine cables, and especially the great oceanic one which spans the Atlantic. The first submarine cable dates only from 1850, and already we have more than 3000 miles of wire rope traversing the seas of the Old and New World. The following table will show the reader at a glance the progress which has been made in marine telegraphy.

TABLE OF SUBMARINE CABLES.

Route.	Date.	Miles.
Dover and Calais	1850	24
Dover and Ostend	1852	76
Holyhead and Howth	1852	65
England and Holland	1853	115
Portpatrick and Donaghadee (two cables)	1853	26
Italy and Corsica	1854	65
Corsica and Sardinia	1854	10
Denmark—Great Belt	1854	15
„ Little Belt	1854	5
„ Sound	1855	12
Scotland—Firths of Forth and Tay	1855	5
Black Sea	1855	400
Soland, Isle of Wight	1855	3
Straits of Messina	1856	5
Gulf of St. Lawrence	1856	74
Straits of Northumberland	1856	10
Bosphorus	1856	1
Gut of Canso, Nova Scotia	1856	2
St. Petersburg to Cronstadt	1856	10
Atlantic Cable — Valentia Bay to Trinity Bay	1858	2500
		3423

Every day, moreover, is adding to the deep-sea telegraph. Whilst we write, the Channel Islands are knit by a new tie to England, and Mr. Thomas Allan, of Edinburgh, one of the most ingenious and energetic promoters of telegraphy, makes public additional plans for rendering Great Britain independent of the Continent in signalling to her Colonies, and encourages us to expect a Universal Oceanic Telegraph, which will speak across the sea from the Anglo-Saxon mother to all her widely-scattered friends and children.

Fig. 11.*



Of these cables we have already described the construction of the first, which, on the whole, may be taken to represent the simpler form of submarine cables. The accompanying diagram in addition to the description given at page 56, will distinctly illustrate its construction.

All other electric cables, however, are as yet of trifling interest when compared with the Atlantic one, and we shall devote the brief remainder of our pages entirely to a description of it. A submarine telegraph wire consists essentially of a metallic thread of no great thickness, and a covering of gutta percha. It thus corresponds to a drawing pencil, the wood of

* *Fig.* 11. *a.* Copper wires, each with the sea as return conductor, acting as a separate telegraphic line.

b. Gutta percha coating the wires.

c. Covering and packing of tarred hemp.

d. Outer sheathing of iron wire.

which represents the insulating sheath of gutta percha, and the *black lead* the electric conductor within. Nor so long as it retained its integrity, would any more complex arrangement be required for crossing the greatest ocean-space, than a copper wire, of the diameter of a bell wire or knitting needle, with as much gutta percha round it as would make a cylinder the size of an ordinary pencil. Could we succeed, moreover, in sinking, without injury, such an insulated wire in the depths of the Atlantic, and lay it intact along the bottom of the ocean in certain of its regions, it might remain unaltered for an indefinite period. Now, though the bottom of the Atlantic is, in many places, rugged and uneven, disturbed by currents, and liable to volcanic disturbance, it is not so everywhere. The excellent and indefatigable Lieutenant Maury, of the United States Navy, has pointed out that a vast plain, which he prophetically named the Telegraph Plateau, stretches between Cape Race in Newfoundland and Cape Clear in Ireland. It is a gently levelled plain or steppe, about 400 miles broad from north to south, and some 2500 long from east to west. Were it an absolute level, it would be only 1640 miles in length, but it dips in mid ocean, and is elsewhere waved into gentle undulations, so as to attain the length first named. Its depth throughout the greater part of its area is about two miles, and therefore far beneath the lowest point to which ships' anchors ever reach, or fishes go. The bottom of this great sea-plain consists of soft mud drifted to it from more disturbed regions. To the naked eye this mud appears a mere wet paste, but it changes, under the microscope, into a countless multitude of the most minute dead calcareous shells and tiny siliceous skeletons of the humblest marine creatures. Life, unless in its most rudimental forms, and as expressed through the minutest organisms, is unknown in these silent regions, and this great valley of the dead is far removed from the present Atlantic centres of volcanic or earthquake action, and is too deep beneath

the surface to be stirred by the mighty Gulf-stream, or vexed by the wildest hurricane. Could we but deposit our slender wire in the soft mud along this portion of the sea-floor, we might with great confidence count on its becoming slowly encrusted with a calcareous and siliceous shield, which would daily increase its freedom from risk of injury.

The actual Atlantic cable differs from the simplest conceivable one in the following respects. As one wire would readily be broken, seven wires of copper are arranged together throughout the greater part of the cable. They lie side by side, and are equivalent electrically to a single wire. The strand or rope which they form is then insulated, and as the perfection of the insulating covering is of the utmost importance, a triple coating of gutta percha envelopes the sevenfold bundle. The gutta percha, however, is liable to mechanical and chemical changes, to protect it from which it is wound round with many strands of tarred hemp. This, in turn, to protect it from injury, is enclosed in a sheathing of eighteen wire ropes, each consisting of seven wires of soft iron, arranged together like the seven copper wires which form the central electric conductor. Altogether, we have a central sevenfold working wire of copper, a triple waterproof insulating covering of gutta percha, a felted protective girdle of tarred hemp, and an eighteenfold coat of iron armour, each component of which is in its turn sevenfold, so that the whole combines the strength, impenetrability, and flexibility of a shirt of chain mail. The following drawings (*Figs.* 12, 13, 14), will illustrate this: the two first are taken from pieces of the actual cable, the third represents it as if dissected.

The cable, assuming its length to be 2500 miles, contains, as stated by Professor William Thomson, 97 tons of copper, 270 tons of gutta percha, 241 tons of tarred hemp, 1692 tons of iron; amounting altogether to 2300 tons, or less than a ton for each mile. As it is of great importance to realise the enor-

mous amount of metal and gutta percha which the cable contains, the following calculation, also from Professor Thomson,

Fig. 12.*

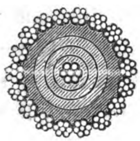


Fig. 13.

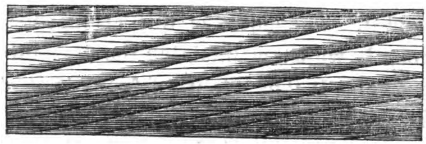
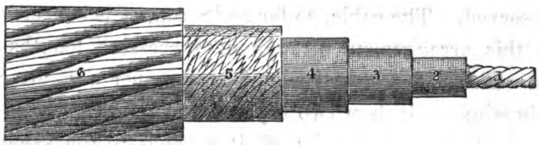


Fig. 14.



is given in illustration of this point. The copper of the cable would form a column 10 feet square and 4 feet high; the iron, a column 10 feet square and 72 feet high; the gutta percha, a column 10 feet square and 52 feet high, besides some thousand cubic feet of hemp.

The following particulars also deserve attention. The copper wire is of the gauge or size known in commerce as No. 22, which corresponds to a small knitting needle. The metal is ascertained

* *Fig.* 12. Section of Atlantic Cable. In the centre are shown the seven copper wires, which, together with the sea as return conductor, form one telegraphic line. On the outside of the circle appear the eighteen iron strands, each consisting of seven wires. Between the centre and circumference appear the sections of three coats of gutta percha, and one of tarred hemp.

Fig. 13. Profile view of Atlantic cable, actual size, showing the spiral arrangement of the iron strands, and of the wires forming each strand.

Fig. 14. Atlantic cable dissected.

1. Sevenfold copper conductor.

2, 3, 4. Coatings of gutta percha.

5. Covering of tarred hemp.

6. Eighteen-fold sheathing of iron wire.

to be very pure, for some samples of copper conduct electricity twice as well as others, which are to appearance equally good. The central copper wire runs quite straight through the cable, whilst the other six copper wires are twisted, or lie in spirals round it. The object of this arrangement is to increase the strength, whilst maintaining the flexibility of the conductor as a whole. It thus admits of being bent almost as readily as a hemp rope, whilst any disrupting force tending to break it, acts unequally on each of the seven wires, and so long as one of them remains unbroken, the electric continuity of the conductor is preserved. The cable, so far as its copper is concerned, presents this arrangement throughout successive lengths of two miles. These lengths are spliced by a copper wire attached by firm brazing, an inch or two beyond the point of junction on one side, tightly wound round until it reaches to the same extent on the other side, and then firmly brazed on again. A second copper wire is then brazed over the first in the same manner, and extended a little way beyond it. The object of this mode of splicing is to secure electric continuity, even should the copper be exposed to a strain so great as to pull the opposite ends of two lengths asunder. In such a case the spirals, unless severely strained, would unrol without breaking, and preserve the continuity of the conductor.

The gutta percha employed in covering the copper is very carefully purified, and, whilst in the plastic condition which heat gives it, is drawn over the wire, which, after receiving a triple coating, is thoroughly tested as to its complete insulation. As the gutta percha slowly alters in composition, and loses its useful qualities under the influence of light and oxygen, a coating of hemp, soaked in a mixture of pitch, tar, oil, and tallow, is placed over it, and serves the additional purpose of forming a soft bed in which the iron ropes can inlay themselves, so as to wind firmly round the central components of the cable. Finally, the iron is coated with tar to prevent it from rapidly rusting.

When, in the course of depositing it, the cable was spliced, the copper wires were laid bare by removal of the gutta percha, and then brazed together in the way already described. Several layers of gutta percha were thereafter carefully laid over and round the joint, by means of hot irons, and after this treatment the outer components of the cable were firmly closed over it. The completed cable weighed from nineteen hundredweights to one ton per mile, and bore with impunity a direct strain of four tons upon its strands.

After the cable had been thus constructed, two important questions remained undetermined. First. Would it be possible to lay it safely along the Telegraph Plateau? Secondly. Supposing it laid uninjured at the bottom of the sea, would it certainly convey electrical currents in such a way as to serve the ends of telegraphy? It is plain that, unless the last question could be answered in the affirmative, it was needless to consider the first. Now, although the length of the Atlantic Cable would have presented no formidable obstacle to signalling through it, had it been a naked wire passing through porcelain insulators as in the Aërial Land Telegraph, the actual case was very different, seeing that the wire was covered throughout by an insulating medium, and that this in turn was coated by a mass of metal. Reference has already been made (p. 60) to the effect of encasing the wires of the subterranean telegraph in gutta percha, in determining certain electrical conditions similar to those of a Leyden jar, and of the interference of these with the action of the wires as transmitters of electricity. A submarine cable presents those unfavourable electrical conditions still more markedly than a subterranean one, and we must now look a little at this important matter.

In the aërial telegraph, where the wires are stretched between poles, and insulated only at long intervals by glass or stoneware holders, the wire, which, in greater part, is surrounded by the air, may be considered equivalent to a tube through which a

current of electricity flows in a continuous stream with a velocity almost immeasurable, even for considerable distances.

In a submarine cable, however, which, as reduced to its simplest components, consists of a copper wire covered by gutta percha, we have, after it is wetted, the following state of matters. The gutta percha, a non-conductor or insulator, is placed between two excellent conductors, the one the copper, the other the water. In the actual complex cable, the gutta percha and tarred hemp together constitute a central non-conducting insulator placed between two metallic conductors, the one the inner bundle of copper wires, the other the outer bundle of iron ones. This, it will be seen, is in both cases exactly equivalent to the arrangement of matters in a Leyden jar, where glass takes the place of gutta percha (which, however, would do better), and two sheets of tinfoil, one inside and the other outside, constitute the metallic conductors. A submarine cable, indeed, is not only *virtually* a Leyden jar, but closely resembles that instrument in its earliest forms of construction. The original "Leyden bottle," like the simplest insulated cable, had water as one of its conducting components, the other being the moist living hand of the experimenter who held it. And a well-known electric toy constructed by the inventors of the Leyden jar, and called the *electric cane*, consisted of a glass tube lined with metal up to a certain height inside, and covered outside to the same height by a sheathing of tinned iron painted to resemble wood. The mouth of the tube was closed by a metallic covering communicating by a wire with the inside coating, and the whole exactly resembled an ordinary silver-headed or gold-headed walking-cane. It was in reality, nevertheless, a Leyden jar, which could be charged in the ordinary way by holding either end to an electrical machine, and could be handled without receiving a shock by anyone careful not to touch simultaneously the metallic head and the metallic sheathing. Those unaware of its construction, however, were almost certain, in

grasping it, to touch the head with the palm of the hand and the sheathing with the fingers, and so to discharge it through the hand. This *shock-stick*, it will be seen, exactly represents the Atlantic Cable, if we suppose the glass replaced by the hempen-coated gutta percha. If, moreover, the reader will recall the numbers already given as representing the weight and mass of metal in the cable, or will here notice that the entire length of wire (copper and iron), calculated by the Directors of the Atlantic Telegraph Company as required for their cable, "amounted to 332,500 miles, or enough to engirdle the earth thirteen times," he will appreciate the fact that this insulated wire rope is equivalent to an enormous Leyden jar, which may receive a powerful charge.

That it would infallibly acquire a charge when connected with a Voltaic battery was certain from the early experiments of Volta himself; but no one was prepared for submarine cables acquiring, in such circumstances, the powerful charge which they are on trial found to receive.

In actual fact, when the conducting wire of a subterranean or submarine telegraph is connected with (for example) the copper end of a battery, so that a current of positive electricity flows along it, it acquires a charge of positive electricity as if it had been connected with the prime conductor of a friction machine, whilst the iron sheathing acquires a corresponding charge of negative electricity. The wire now passes into a state of apparent electrical quiescence, but in reality of electrical tension, such as characterises a charged Leyden jar, and, till it is discharged, can receive no farther addition of *positive* electricity. If the wire were originally connected with the zinc end of the battery, we should have a similar state of matters induced, with the exception that the inner copper would now be charged *negatively* and the outer iron *positively*. Whereas, accordingly, along an uncovered suspended wire, we can send a continuous stream of electricity, and thereby produce continuous signals at the

receiving station,—along a covered insulated wire we may produce a signal in the act of charging the wire, but must then stop till we discharge it. The uninsulated arrangement has been justly compared to a pipe open at both ends, which empties as fast as it fills; the insulated arrangement to a pipe shut at one end, or a bottle which, after being filled by one process, must be emptied by a reverse one before it can be filled again. We are able, as it were, with the latter arrangement, to produce a signal whilst filling the bottle, but must lose all the time occupied in emptying it before we can produce a second signal in the act of refilling it; and although the alternate emptyings and fillings occupy very brief periods, these are sufficiently long to lessen greatly the rate of signal-transmission along the insulated wire.

Nor are these the only difficulties attaching to submarine telegraphy. A charged Leyden jar, if left to itself, slowly effects its own discharge; in other words, gradually restores itself to its original neutral electrical condition. But this it cannot do without the copper conductor becoming the seat of electric excitement, and when thus disturbed it acts on the index at the receiving station, as if it were conveying a current sent along it to produce a signal. Further, an insulated wire is greatly more sensitive to electrical disturbance by the influence of electrical action in its neighbourhood than a suspended wire, and thus responds to changes in the earth's magnetism, and to the passage of natural currents of electricity, as well as to all the terrestrial, atmospheric or marine forces which develope electricity, in a way that seriously increases the task of making it the medium of rapid and continuous telegraphic signals.

From what has been said, it will be manifest that peculiar arrangements are needed for signalling along insulated lines. One object of these is to effect the alternate charge and discharge of the conducting wire, which is secured by sending alternate positive and negative currents along the line. Prac-

tically, this is equivalent to successive fillings and emptyings of the hypothetical bottle, and is a quicker process.

More truly, the insulated wire may be compared to a vessel containing an acid when charged with the one electricity, and an alkali when charged with the other; and we may suppose signals to be produced by the one turning a vegetable purple red, and the other the purple green. Instead of washing out either acid or alkali by plain water, we neutralise it with the other, or rather we use an alternate excess of each, and employ that excess in producing a signal. Thus a single drop of acid will turn a vegetable purple red, and a single drop of alkali will turn it green. The uninsulated wire allows us, as it were, to employ the needful drop, and no more, of either, as we wish to produce a red or green signal, and thereafter to wash the reagent away, restoring the original purple. The insulated wire again compels us, as it were, to apply one thousand drops (for example) of the acid, and it is much easier to over-neutralise that by two thousand of alkali, and change the signal from red to green, than it is exactly to neutralise it and produce the purple. Two thousand and odd drops of acid will again give us red, and so on infinitely. We may either signal only when the acid is acting, or only when the alkali is, but we shall plainly double our speed of signalling if we use both.

The other object is to neutralise the influence of terrestrial currents by opposing ones furnished by a special or protective battery. As originally planned by Mr. Whitehouse, the ingenious electrician of the Atlantic Telegraph Company, the arrangements for signalling across the Atlantic were as follows:—

1. A large galvanic battery (or rather pair) furnished electricity abundant in quantity.

2. The current from this battery was entirely spent in traversing a comparatively thick silk-covered wire more than a

mile in length, and wound into a multitude of coils. This is called the *Primary* or *Battery* Coil.

3. Within this first coil lay a second, consisting of thinner covered wire, and many miles in length. It had no metallic connexion with the first coil, from which it was separated by a thick sheet of gutta percha. This is called the *Secondary* or *Transmission* Coil.

4. In the centre of this secondary coil lay a bar of soft iron covered by gutta percha, and called the Electro-Magnetic *Core*.

The arrangement thus far constitutes one of the forms of what is called a *coil machine*. When a battery current flows along the thick short (primary) wire it developes or induces in the neighbouring thin (secondary) wire a current of electricity. The battery and secondary currents likewise develope magnetism in the iron core, and its magnetic excitation reacts on the electric current in the secondary wire, greatly increasing its intensity. Altogether, by this combination of wire coils and a temporary or electro-magnet, a current is procured from the secondary wire, far exceeding in intensity that which the battery sends along the primary wire. This secondary current accordingly is transmitted through the cable, say from Ireland to Newfoundland; and there may be directly employed to produce signals, but by preference it is expended in calling into action:—

5. A local or relay battery, which, in its turn, actuates

6. A needle, a Morse's style, or a Bain's electro-chemical pen, and thereby produces a temporary or permanent signal.

There are thus, 1, a generating battery; 2, a coil-machine; 3, an insulated cable; 4, a relay battery; 5, an index or recording instrument; 6, the sea acting as a return-wire. The battery *produces* a current of a certain intensity. This *induces* in the coil-machine a current of far higher intensity. This intense coil-current passes along the cable, and, at its further end, by

means of an electro-magnet which it makes, calls into play a relay battery, and thereafter returns by the sea. The current of this relay produces the signal.

In actual fact, however, a large number, if not the majority of the signals which have hitherto been sent along the Atlantic Cable, were transmitted directly from a Daniel's Battery without the intervention of a coil-machine, and, after crossing the Atlantic, acted directly on a signalling apparatus without the intervention of a relay battery. The signalling apparatus in this case was a most beautiful and ingenious instrument, invented by Professor William Thomson, of Glasgow, and called by him a reflecting galvanometer. It consists essentially of a very small magnetic needle armed with a mirror, and surrounded by a coil of wire like the ordinary telegraph needle. The light of a lamp is thrown on the mirror, which reflects its image through a lens on a distant screen. A spot of light is thus produced, which follows, but at the same time immensely exaggerates the movements of the needle, so that its deflection for an inappreciable hair's-breadth carries the spot of light through a space of many inches. The feeblest currents are sufficient to actuate this sensitive instrument, and by means of the Morse "dot and dash alphabet" the motions of the spot of light are made to represent words with abundant facility and accuracy. In truth, the instrument is too sensitive, and by its over prompt obedience to earth-currents disturbs the signalling; but even this difficulty has been obviated by the singularly accomplished mathematician who has invented this galvanometer. The remedy consists in neutralising the earth-current by sending one of equal force from a special battery, whilst the current of another battery, more powerful than either of the other currents, is employed to transmit signals. That none of those precautions are unnecessary will appear from the fact, that whilst on uninsulated land-lines twenty words per minute can be signalled by Morse's or Bain's machines, and forty-five per minute by Wheatstone's

double needle, three words per minute are the most that have yet been attained along the Atlantic Cable. It must be remembered, however, that the full capabilities of the Atlantic Cable in a state of perfect insulation have not been ascertained, and that thus the skill and ingenuity of the electricians have to a great extent been thrown away. Moreover, an arbitrary alphabet employing fewer letters to each word would materially quicken the rate of signalling.

As to the second question, can a cable be laid in good order at the bottom of the Atlantic? that, too, must be regarded as certainly admitting of an approximate positive reply; although it is plain that in the process of laying it is liable to serious and even fatal injury. The best mode of laying a very long deep sea-cable, and its best mode of construction, remain to be ascertained.

Meanwhile, the possibility of successfully telegraphing across the Atlantic has been put beyond doubt, and a perfect line will be established before long. For this, considered as an electrical feat, the world is mainly indebted to two of our countrymen, Mr. Wildman Whitehouse and Professor William Thomson. The latter especially,—as the electrician who accompanied the Agamemnon in both its recent momentous and perilous voyages, and as the inventor of the beautiful instruments by which messages have been chiefly sent between the Old and New Worlds, as well as one of the most profound expositors of the laws which regulate the transmission of electricity—deserves most honourable mention. A striking parallel might be drawn between Christopher Columbus, three centuries ago, observing for the first time in mid-Atlantic the compass-needle cease to point north and veer round to the west, as if signalling *Westward Ho!* and William Thomson in the same ocean watching for the first time the motions of a mirrored compass-needle swaying to and fro, as hour after hour it counted the diminishing steps by which, in another fashion, the Old and New Worlds were becoming linked together.

Entertaining those feelings, the present writer looks upon the temporary failure of the Atlantic Telegraph as no more than a brief trial of patience, and ventures, accordingly, to insert here some lines on its completion, which have already appeared in "Blackwood's Magazine."

It is customary, in referring to the Atlantic and other submarine Telegraphs, to mention only the submerged cable, as if that constituted the entire telegraph. In reality, however, the cable forms but one-half of the requisite electric circuit, the other and equally essential half being furnished by the ocean. Thus, excluding from consideration the small portions of land occupied above water-mark, on either side of the Atlantic, by the station-houses nearest the brink of the sea, the cable, some two thousand miles long, conveys the electric current from shore to shore in one direction, and the sea conveys it in the other. Such a double channel must be provided in all telegraphs, and the half supplied by the earth or sea, although it costs nothing, is as important as the insulated metallic half which is so costly to produce, and so difficult to preserve in working order. The Atlantic Telegraph, accordingly, when considered as a link of union between the Old and New Worlds, cannot be compared to the ordinary wedding-ring, a circle consisting entirely of metal. Its symbol is one of those finger-rings at present out of fashion, where a part only of the circle is gold, the remaining portion consisting of a jewel held between the ends of the golden crescent, and completing the circle. If we suppose the stone in such a ring to be that which jewellers term the "Aqua Marine," we shall have a perfect symbol of a Submarine Telegraph.

Since the lines which follow were written, an unexpected derangement of the Atlantic Cable has stopped the working of the telegraph. But even if the worst apprehensions are realised, and no future signal pass along it, it must for ever be sacred in the eyes of the historian and poet. The wedding of the Old and the New World is an accomplished fact, and the

thread-like wire which conveyed across the Atlantic the Angelic Song, as the first greeting from the Fatherland, has, in one sense, done its work. Nor is there any reason to doubt that the wise, and brave, and patient men who have so nobly carried out this great enterprise, will before long reap the full reward, as they have already gathered the first-fruits, of their labours.

"THE way is far across the sea,
My Daughter," England said :—
"Thy Land and mine each other love,
'Tis time that they should wed."—
"The way is far across the sea,"
America replied :—
"Thou hast the Bridegroom, Fatherland,
And I the willing Bride."

"Doth any one forbid the bans ?
Will any one declare
Why these should not be wedded,
This long betrothëd pair ?"

Then rose the nations of the world,
And shouted as one man :—
"Wed, Anglo-Saxons, if ye will !
Wed, rather, if ye can."

"Who talks of weddings ? We forbid
The banns :—the Atlantic gales
That shatter ships, and slaughter men,
And turn to shrouds their sails.
Ho ! cease thy vauntings, Bridegroom bold,
And stay thy longings, Bride,
The Wedding-Ring shall never pass
Across the stormy tide."

"Nay! hush your voices, angry winds,
We'll bide our time and go,
When in the sleepy sunshine
Ye scarce flit to and fro.
From east to west our ships shall sail
In calm and sunny weather :
In middle-sea we'll keep our tryst
And join our hands together."

Then rose a voice, sweet, soft, and clear ;—
The Earth spake to the Sea :—
"I will give half the wedding-ring,
If half is given by thee.
My half shall be this costly chain,
Copper and dusky steel,
Woven together, and darkly clad,
To last through woe and weal.
It bendeth like a crescent moon ;
If thou wilt place between
Its crescent horns, like jewel-stone,
Thy waters, emerald green ;—
Then we together shall complete
The wondrous wedding-ring,
Round which the Silent Lightnings
Their voiceless flight shall wing."

"Thou art a Queen, O Ancient Earth !
And I a King of old ;
The Brides of Venice wedded me
With many a ring of gold.
But better far than golden ring,
I'll prize thy darksome chain ;
The beryl of my purest depth
Shall help to wed the twain."

"O ! promise not too much, thou Earth !"
Exclaimed the scornful wind ;
"Thy wedding-gift is strong indeed
If I no flaw can find ;
And trust thou not too much the Sea,
He is my Vassal-slave :—
His wrathful hands to mar thy gift
Shall start from every wave."

The wisest of the Sons of Men
Had heard the speaking Three :—
"We will not fear," they said, "the Wind,
We'll trust the Earth and Sea."
They drew the Lightning from the sky,
They quenched its torch of fire,
They flung its thunderbolt away ;—
Along a tiny wire

They made th' impatient spirit pass;
  Its thunder-voice was still —
But they left its shoes of swiftness
  That it might do their will: —
Before an eyelid rose and fell,
  Ere scarce the words were given,
It could engirdle Earth and Sea
  With its lightning-pace of Heaven.

On England's shores through many a day
  And night they forged the chain,
A thousand, thousand miles in length
  To stretch across the main.
Within the stately battle-ships,
  Through many an hour of toil,
Like two great sleeping serpents,
  They wound it coil on coil.
One ship was from the Bridegroom-land,
  And one was from the Bride,
And so they sailed together
  Across the Atlantic Tide.
They steered across the exulting Sea,
  Straight for the middle-deep,
That Bridal-land and Bridegroom-land
  Their settled tryst might keep.
And there about midsummer-time,
  Like lovers who have broken
A ring in twain, and each one-half
  Keeps as a troth-plight token
Till they can join the halves again,
  They welded fast the link
That wove the kindred coils in one,
  And watched the welding sink
Beneath the Sun, the Stars, the Sea,
  Till it could sink no more;
And then its prow each good ship turned
  Home to its native shore.
One sailed to East, and one to West:
  Between, they unwound the chain,
Down deepest ocean-valley
  Along the deep sea-plain.
From ship to ship along the line,
  Where death and silence dwell,

The voiceless lightning went and came,
And signalled "All is well."
Onward by night, onward by day!
They saw arise and set the sun;
They counted all the anxious hours,
And thought their work was done.

Then rose the Demon of the Storm,
And lashed the Vassal-sea,
Until with desperate hands the link
He broke in his great agony.
"O take the chain thou lovest so well,
I love it not, I wiss!
Take chain and ships, take men and all,
Down to thy dark abyss."

Twice did the sore-reluctant sea
Shatter the costly chain:—
Twice did the half-despairing crews
See all their work in vain.
But they who manned the ships *were* Men,
The bravest of the brave,
Who vowed they'd sit at bridal feast,
Or lie in honoured grave.

And when the third time, unappalled,
They sought the middle-deep,
He whom the Winds and Waves obey
Had hushed them both asleep.
And though the chill divorcing wind
Knew but a restless rest,
And tossing in its night-mare dream
Ruffled the ocean's breast;
Yet cheerily the ships sailed on,
Cheerily west and east:
"We bring the ring: Go call the guests,
And pray the wedding-priest."

They sailed by night, they sailed by day!—
The long betrothëd lands
From Bridegroom passed to Bride the ring,
And joined their willing hands.
Loud when the ships had reached each shore,
The cannon spake in thunder;

"Whom God hath joined," they seemed to say,
"Let no man put asunder."
And then around the wondrous ring
The blessed greeting ran,
"Glory to God! On Earth be Peace,
Goodwill to every man."

So now, methinks, this Earth of ours
More like to heaven should be,
When we have seen an end of Time,
And there is no more Sea.

GEORGE WILSON.

INDUSTRIAL MUSEUM, EDINBURGH,
September, 1858.

THE

CHEMISTRY OF THE STARS;

AN ARGUMENT

TOUCHING

THE STARS AND THEIR INHABITANTS.

THE

CHEMISTRY OF THE STARS.

In discussing the Electric Telegraph, we have wandered in thought, far and wide, over our globe; but in our boldest flights we have not looked beyond our Home-Earth. But the same spirit which showed itself in the famous spoiled child of antiquity, Alexander the Great, when he wept that he had not another world to conquer, is in the hearts of us all. If the ends of the earth were knit together by all-embracing electric links, we should begin to sigh that we could not stretch them further, and long to entangle in their thrilling meshes, some one, at least, of the distant stars. And without waiting for the electric conquest of the earth, we are ready at all times to take up the Grecian Conqueror's lamentation; or what is better, to stifle our tears, and be visionary warriors triumphing on visionary battle-fields, and dream-kings reigning over a dream-land. Thought, which is swifter than electricity, can waft us anywhere, and whispers at our will the "Open Sesame" of the Universe. We propose with its telegraph to go forth into Space, and see if we can obtain any answer to our questionings concerning the Nature of the Stars and their Inhabitants.

We shall take for granted that they possess inhabitants, or rather shall put the question thus: "If the stars are inhabited, is it probable that the dwellers on them resemble those on this star, or Earth, or is it more likely that they are non-terrestrial

beings, unlike us, and our plant and animal companions, and different in different stars?"

We are not anxious to compel the conclusion, that all the stars are inhabited. Many of the excellent of the earth have held that they universally are, and that, too, by rational creatures; and have thought that the denial of this did injustice to our own convictions, and to the omnipotence and bounty of God. But our standard of Utilitarianism can never be a safe one by which to estimate the works of him whose ways are not as our ways, nor does it require the view supposed.

It would not be a painful, but a pleasant thing, surely, to learn that some of the stars, such as the new planet Flora, were great gardens, like Eden of old before Adam was created; gardens of God, consecrated entirely to vegetable life, where foot of man or beast had never trod, nor wing of bird or insect fanned the breeze; where the trees never crackled before the pioneer's torch, nor rang with the woodman's axe, but *every* flower was

> "Born to blush unseen,
> And waste its sweetness on the desert air."

Neither is it the remembrance of the Arabian Nights, nor thought of Aladdin's lamp, that makes us add that we should rejoice to learn that there was such a thing as an otherwise uninhabited star, peopled solely by magnificent crystals. What a grand thing a world would be, containing, though it contained nothing else, columns of rock crystal like icebergs, and mountains of purple amethyst, domes of rubies, pinnacles and cliffs of emeralds and diamonds, and gates and foundations of precious stones, such as John saw in the Holy Jerusalem descending out of heaven! All who reach the Happy Land are to enter heaven as little children, and it may please God, besides other methods of instruction, to teach his little ones his greatness and his power, by showing them such a world as we have imagined.

And even if some heavenly messenger, "Gabriel that stands

in the presence of God," or one of the other angels that excel in strength, should descend amongst us, and proclaim, "There is no life of any kind in any star but the earth," should we be entitled to murmur at the news. Such is the pride and selfishness of man, that he does not hesitate to proclaim any world a desert, from which himself or his fellows are excluded. But even if it should be certain that every star but the earth is a ball of lifeless granite, or barren lava, it would be for us, if we were wise, to say of it, as the Psalmist would have said, "Whither shall I go from thy Spirit? or whither shall I flee from thy presence?" In the most deserted and solitary of worlds, as we might call it, God is present. The fulness of him that filleth all in all, fills it; the Saviour and the Holy Spirit are there. If our ears were not stopped like the deaf adder's, we should, if visitants of such an orb, hear a voice say, "Put off thy shoes from off thy feet, for the place whereon thou standest is holy ground." We leave, then, the question of the universal habitation of the heavenly bodies untouched, and intend, moreover, to refer chiefly to the nature of the stars, and not to that of their inhabitants. The character or quality of the dwellers in the heavenly bodies is, doubtless, a more generally attractive topic than that of their habitations, as most thoughtful men would consider a forlorn and degraded savage a more truly interesting object than the grandest palace. Our only hope, however, in the meanwhile, of ascertaining anything concerning the dwellers in the stars, is founded upon what we can discover concerning the stars themselves.

The direction in which our argument must proceed may be stated in a word. If we made out a rude structure on the summit of a cliff, to have all the characters of an eagle's nest, we should fairly enough infer that its inhabitants were, or had been, eagles; if we were satisfied that another erection was a beaver's dam, we should judge that beavers dwelt within. A

bee-hive would imply bees; a burrow, foxes; a mole-hill, moles; and so, if, among the heavenly bodies, we discover stars identical with our earth, we may pretty safely infer that they are, or may be, or may have been, inhabited by beings like ourselves. Direct observations on the dwellers in the stars, if dwellers there be, it is not likely we shall ever succeed in making. Of the inhabitants of the sun we shall probably never know more, than that the apostle John saw in vision an angel in it; and as for the nearest of the heavenly bodies, we may be thankful that in early life, we saw with our own eyes, as the reader knows he did, *the* man in the moon, as it is not likely that any of us who have reached maturer years shall ever see him again. Isaac Taylor thinks that our sun "may be a world of bliss, the abode of creatures endowed with incorruptibility and immutability;" in a word, Heaven. Others, whose names we are glad to leave in oblivion, have looked upon the sun as the world of woe. John Foster thought that its inhabitants might be "square, orbicular," or, as he shrewdly adds, "of any other form." We are not about to emulate these authors. The question we shall try to answer is the much simpler one,—"Are the stars and their inhabitants terrestrial or non-terrestrial, earthly or non-earthly?"

Great men have held it probable that the stars are terrestrial in nature,—i.e. fashioned of the same materials, and generally constructed like the earth. Sir Isaac Newton was of this opinion. So, to some extent, were Laplace and the elder Herschel. Humboldt has adopted it, and Mulder, the distinguished chemist of Holland. Isaac Taylor, in his "Physical Theory of Another Life," has enlarged upon it with characteristic ingenuity and eloquence. It has been widely brought before the public by Professor Nichol, and the author of the "Vestiges of the Natural History of Creation," and thus it has become a subject of popular interest.

The question may at first sight appear to be one, which,

however attractive to the unscientific, cannot be pronounced upon by them; and such certainly is its character. Yet it may be curious to inquire what the decision of the general public is likely to be on a subject so alluring to unreined speculation; and it has been strongly held by certain of the advocates of the telluric or terrestrial nature of the heavenly bodies, that the untutored perception of analogy, and the unaided common sense of mankind, would justify the conclusion which they favour. Nay, it has been urged that the prejudices of the more lettered and scientific portion of the public incline them to prefer the theory of a non-terrestrial chemistry, although it is difficult to see how this can be the case. To satisfy all parties, however, we shall in the first place try, if possible, to learn what the so-called common sense verdict is, or rather would be; and as we can appeal to no existing document as formally recording it, we shall suppose a jury impanelled to try the question of the chemical identity of our globe and the sidereal universe.

All fellows of colleges and of royal societies shall be excluded: all doctors of all kinds, all professors, lecturers, and the teaching class: all clergymen, lawyers, naval and military officers, civil engineers, and in general every man who puts a title before, or prints letters after his name. All critics, reviewers, writers of books, and every one else, professionally or systematically connected with scientific or with literary polemics, shall likewise be protested against; and whosoever, moreover, can be shown, on the faintest suspicion, to have made science, however slightly, a matter of study. From the residue of mankind, after the roll has thus been purged, twelve honest men and true shall be chosen, as strongly gifted with common sense as can be found. These shall form our grand jury. The case shall be tried on successive midnights, in the open court of heaven, and the cause shall be argued according to a precedent supplied by Napoleon, though not to be found in the

Napoleon Code. When the First Consul crossed the Mediterranean on his Egyptian expedition, he carried with him a cohort of savans, who ultimately did good service in many ways. Among them, however, as might be expected at that era, were not a few philosophers of the Voltaire-Diderot school. Napoleon, for his own instruction and amusement on shipboard, encouraged disputation among these gentlemen; and on one occasion they undertook to show, and, according to their own account, *did* demonstrate, by infallible logic and metaphysic, that there is no God. Bonaparte, who hated all idealogists, abstract reasoners, and logical demonstrators, no matter what they were demonstrating, would not fence with these subtle dialecticians, but had them immediately on deck, and, pointing to the stars in the clear sky, replied, by way of counter argument, "Very good, messieurs! but who made all these?"

We shall judge this case in the same way. The stars themselves shall be appealed to for a reply to the question we are curious to have answered. They shall appear at the bar, and learn that a charge has been preferred against them, that "they are of the earth earthy." The question shall be put to each, "Earthly or not earthly?" and the jury shall give their verdict according to the answer returned. Our twelve honest men, then, having sworn in the presence of the great Judge to give a righteous verdict, shall be taken to the summit of some heaven-kissing hill, and left there as long as they please, to make acquaintance with the stars. Far away from anxious author and captious critic, they shall read for themselves the lesson of the universe. The heavens shall declare the glory of God: the firmament show his handiwork. Day unto day shall utter speech in their hearing: night unto night show knowledge before them. They shall watch the guiding of Arcturus and his sons: and behold the bands of Orion: they shall feel the sweet influences of the Pleiades, and listen to the morning stars singing together. "The Sirian star, that maketh the

summer deadly," shall shine forth before them on the forehead of the sky, and they shall hearken to the solemn tread of the host of heaven, as, drawn up in their constellations, they nightly repeat their sentinel march from horizon to horizon.

And when the unsatisfied senses are still filled with desire, all needful help shall be furnished to gratify their longing. The Herschel forty-feet telescope shall be granted our jury to gaze through, and the courteous Lord Rosse will not refuse the giant reflector. Pulkowa, and Altona, and the Cape shall lend the best instruments of their observatories, and the ingenious Lassell shall record for them what he witnesses with his space-piercing tube. The wise and filial Herschel shall stand by to explain; and the eloquent Arago and sweet-tongued Humboldt make the wayfaring man, though a stranger, at home in the universe. As witnesses, however, witnesses only, shall these high priests of nature be called, and speak to facts, but offer no opinions.

Our twelve shall first cast a glance at our own solar system, and observe that no one of its planets has the same magnitude, inclination of axis, so far as that has been observed, density, time of rotation, or arrangement of orbit; but that each, in nearly all these particulars, differs greatly from its brethren. They shall notice that several of the planets have no moons: that our Earth has one relatively very large one: Jupiter, four relatively small ones: Saturn, seven of greatly varying dimensions: Uranus, as is believed, six; and Neptune, two or more. They shall see the splendid girdles which Saturn wears, and be warned that two at least of the moons of Uranus move from east to west, or in a direction opposite to that of their planet, and of all the other bodies of the solar system.

The enormous differences in the length of the planetary years shall startle them; that of Mercury, for example, being equal to about three of our months; that of Neptune, to 164 of our years. The lesser, but marked diversities in the length of their days shall awaken notice, the Mercurial day being, like our own,

twenty-four hours long, the Saturnine only ten. The variations in the amount of heat and light received from the Sun by each of its attendants shall not be forgotten; Uranus, for example, obtaining two thousand times less than Mercury, which receives seven times more than the earth. They shall also observe the extent to which the planets are subject to changes of season; the Earth knowing its four grateful vicissitudes; Jupiter knowing none; whilst the winter in Saturn under the shadow of his rings is fifteen years long. All those unresembling particulars shall be made manifest to our observant twelve. Neither shall they be forgetful of those dissimilarities in relation to atmosphere, and perhaps to physical constitution, which astronomers have detected. When so much diversity has been seen to shine through the unity of the solar system, our twelve shall gaze forth into space, to see if all be sameness there. Sameness! They shall discern stars of the first magnitude, stars of the second magnitude, of the third, of the fourth, of the seventh, down to points so small, even to the greatest telescopes, that the soberest of philosophers can devise no better name for them than star-dust; and one of them declares "that for anything experience has hitherto taught us, the number of the stars may be really infinite, in the only sense in which we can assign a meaning to the word." They shall find that the Dog-star is a sun, whose light has an intrinsic splendour sixty-three times greater than that of our own solar orb, and that he is not counted chief of the stars. They shall search in vain through the abysses for a system similar to our own, and find none, but perceive instead, multitudes of double-stars or twin suns, revolving round each other. They shall learn that there are triple systems of suns, and that there may be more complex ones; and try to conceive how unlike our planetary arrangements must be the economy of the worlds to which these luminaries furnish light. They shall gaze at purple and orange suns, at blue and green and yellow and red ones; and become

aware of double systems where the one twin appears to be a self-luminous sun, and the other a dark sphere of corresponding magnitude, like a sun gone out, as if modern science would assign an exact meaning to Origen's reference to "stars, which ray down darkness." Herschel shall show them the sidereal clusters, many of which "convey the complete idea of a globular space filled full of stars [i. e. suns] insulated in the heavens, and constituting in itself a family or society apart from the rest, and subject only to its own internal laws." Lord Rosse shall exhibit the nebulæ, resolved and unresolved. The continental observatories shall furnish records of those strange heavenly bodies which periodically wax and wane, now shining like "candles of the Lord," now darkening with Ichabod on their foreheads. Tycho Brahe shall tell of those mysterious unabiding stars, which have flashed almost in a moment into existence in the heavens, and have died away like all precocious things prematurely, appearing as if to verify the poet's prediction, that the sun himself will prove a transient meteor in the sky. The Chinese astronomers shall proclaim the paths of ancient comets, which neither Greek nor Roman had courage or science enough to trace through the heavens; and Humboldt, after describing the wanderings of the comets of later days, shall supply the commentary that so great are the differences among these eccentric bodies, "that the description of one can only be applied with much caution to another." The American observers shall detail how thick and fast the "fiery tears" fall from the November meteors: and a thousand other witnesses stand ready to affirm "of diversity there is no end." But we may suppose our somewhat distracted twelve, at this stage of the proceedings, to decline further evidence, and bethink themselves what their verdict shall be.

"These stars!" one juryman will say—a chandler we may guess, or oil merchant, or perhaps only a lamp-lighter—"these stars! these suns! 'these street lamps,' as Carlyle has called

them, 'in the city of God,' are they to be counted, my brethren, so many argand burners, each cast in the same mould, with wick clipped to the same length, and fed with the like modicum of oil, that it may spread an equal number of rays over the same square section of heaven's pavement? Nay! are we not certain that at least they differ in size and brightness? and if thus they vary in dimensions and in splendour, as well as in colour of light and in mode of arrangement, is it likeliest that in other respects they differ only in degree, and have all but one function, or that they differ in kind and in office also? Some shall be likened to fragrant wax-candles, lighting up gay drawing rooms; and others shall be murky torches following the dead to the tomb; and others Eddystone lamps, saving goodly ships from destruction; and others, rainbow-tinted vases, making the streets gay on coronation festivals: or strontia-fires, bidding armies begin battle; or Bude flames, illuminating halls of parliament; or lime-ball and electric lights on lofty mountain-tops, measuring arcs of the globe."

A second of the twelve shall arise, a blacksmith, or stoker, by the look of him. "That visible sun of ours, it should seem, is the open furnace-door of a great locomotive engine, sweeping through space. Its train goes with it, of Jupiter-Saturn first class carriages, Mars-Earthly second class, and Ceres-Vesta third ones; satellite trucks being here and there interspersed through the train; and comet engines provided to go special messages. Those far distant stars, it should seem, are locomotives too, and like enough, propel planet-trains, though no one has seen even traces of the latter. But are we free to settle that each drags its Jupiter, its Earth and Vesta carriages behind it, with the same lord and squire passengers in the first, citizens well-to-do in the second, and stout mechanics or ragged Irishmen in the third? Are the paint and lacquer, the cushions and the paddings, the door-handles and the wheels, and all the similar coach furniture, to be looked for in these hypothetical trains,

exactly as they are found in our sun's planet-carriages? Let us consider before we admit this, how many coupled engines we see; how many triplets and other locomotive wonders, which are likely to have attendants as strange as their engines, and pause before we settle that space is but a railway network, traversed by up and down trains, differing only in length and speed, and carrying in the same vehicles the same kind of passengers and goods, at the one Universal penny a mile.

"It seems, indeed, but an appeal to our ignorance to say, that that Sirius-engine, for example, differs nothing from our Sun-locomotive but in size. Its fire is far brighter and hotter than ours, and perhaps as much because it burns a different sort of fuel, as because it merely burns more of the same coke that our locomotive consumes. Neither does it seem a self-evident proposition that the Sirian machine must be made up of some sixty chemical pieces, because one of the carriages of our Sun's train consists of so many. And as for the train of the Dog-star, if there be one, it appears not unlikely that the traffic of the regions through which it runs may be very different from that of our zodiac, and that the vehicles composing the suite of Sirius may differ in many particulars from such as accompany our Sun. I, for one at least, will say that I perceive no grounds for assuming that where diversity prevails in relation to all the points that are cognizable by us, sameness should be counted to be the rule in regard to everything that is hidden from our sight."

A third juryman, who has plainly served before the mast, will make bold to ask the question—"Those ships of heaven that go sailing past, each on its mysterious God-commissioned errand, were it wisest to consider them a fleet of herring-boats or collier brigs, some larger, some smaller, but all built of the same materials, rigged in the same style, and carrying the same cargo? Or were it wiser to compare ourselves to the watchers on lonely Ascension Isle or solitary St. Helena, now signalling

a man of war with its 'Mariners of England;' then an African slaver with its doleful passengers and demon-crew; now a heavy-laden Indiaman rich with the wealth of China; then a battered South Sea whaler, filled with the spoils of slaughtered monsters of the deep; light Tahitian schooners with cocoa-nuts and arrow-root; stout American ships with ice for the epicures in India; English barks with missionaries, for the heathens of all lands. Oak ships, and teak ships, and ships hammered out of iron: sailing vessels, and ocean steamers with paddles and screw-propellers. Danes, Dutchmen, and Swedes, Frenchmen, Russians, and Spaniards, each with its different build, its unlike dialect, its strange flag and unresembling crew. All sizes and shapes and kinds of navigable craft, with all sorts of unimaginable cargoes and motley companies of sea-faring men.

"If there are all these differences among our sailing vessels, are there likely to be fewer among the ships of heaven? Do you think it probable that if by means of some loudest speaking-trumpet, we could hail each shining orb with 'Star a-hoy!' and thereafter, by means of some farthest echoing reverberating hearing-horn, could get back an answer, that from every one would be returned the same doleful or trivial earthly murmur—*Californian Diggings; Kaffre War; Ministers Outvoted; Fête at Paris; Insurrection in China; His Holiness the Pope's last Bull.*

"My friends think of this. In the azure sea above us, there are no shores or landing-places; it is one boundless PACIFIC OCEAN, where the frailest bark never hides behind a bulwark, or drops anchor in a storm. The fleets of heaven are all phantom ships, for ever sailing, but never nearing port. If they are all then as nearly as possible identical, why are there so many? If the nature and object of each is the same, why are they not pieced together so as to make up one huge vessel? They might as well have been nailed and hammered into a single mighty sun, or sun-earth, lighting up, and darkening

itself, while it floated through space, like a gigantic Noah's ark, laden with every living creature."

This is our Sailor-juryman's opinion; but we have an old Serjeant also among our twelve, and he claims to be heard next. "The Skipper," he begins, "the Skipper has likened the stars to men-of-war, and so will I, though in a different sense from him, but with a view to repeat his question: If the celestial bodies are all alike, why are there so many of them? The stars, I have been told, are the 'Host of Heaven,' 'the armies of the sky,' and if so, are something more than a regiment, and are likely to present other differences than merely a grenadier company of stars of the first magnitude; a light company of stars of the second; a mass of troops of the line, of the third; and drummer-boys of the fourth. An army, my friends, is not a *row* of pipe-clayed men, with stiff stocks and buttoned gaiters, turning their eyes to the right or the left as some martinet colonel gives the word of command. It counts not by men but by companies, not by companies but by regiments, not by regiments but by battalions, not by battalions but by nations. Its officers are dukes and archdukes, kings and emperors. It has cavalry and infantry, artillery battalions, rifle brigades, rocket companies, engineers, sappers and miners. In that small matter of arms and clothing how endless the difference. Plumed bonnet, helmet and shako, grenadier cap, cocked hat; plaid, cuirass, hussar-jacket, broadsword, sabre and spear, bayonet, pistol, carabine and musket: all kinds of dress and equipment, and every variety of weapon, worn by all sorts and conditions of men. And if man, bent only on fighting for his hearth and home, and without caring for diversity, nay, doing his best to provide against it, by 'tailor's uniform,' 'serjeant's drill,' 'pipe-clay,' 'orders of service,' and whatever else promised to smooth over differences,—has never been able to do more than iron straight and make uniform a single regiment at a time, and that for the shortest period, how is it likely to be

with that Host of Heaven as ye call them? Scarcely among earthly hosts has some latest regulation-cap become comfortable on the head of its military wearer, before he who planted it there to realise his thirst for unity, has grown weary of its sameness, and must have the felt shaped anew. This is the lesson that nature has taught him, how not two leaves can be found alike, not even two pease: and if not two alike, still less three: least of all thirty or a thousand. If, moreover, among objects of the same class or species every additional unit shows an additional difference, how much greater the probability of variety, when there is a likelihood of the individuals belonging to different tribes! Call not, then, the heavenly bodies a host, or army, or acknowledge that they must have mighty differences among them. I say not that each 'sentinel star' is unlike all others. It is enough if it be unlike many. There may be whole battalions of the same race, wielding the same weapon, and wearing the same uniform: but will this be the case with the entire army? It was not so with Pharaoh's host, or the Roman legions, with Attila's hordes or Britain's army, or with any host that man has seen. I ask no other evidence of diversity existing among the starry night-watchers than that there are millions of millions of them. Such numbers do not exhaust unity; no numbers can; but they exclude sameness when oneness of species cannot be shown; and before we have counted even our thousands, 'all things, I doubt not, will have become new.' Yes! the faulchion that Orion wields is forged of a different metal from the flaming sword of the comet, or the fiery weapon of Mars, and the club of Hercules is carved of another wood than the shaft of Bootes' spear."

A long-haired, ample-collared young gentleman, will here interrupt our militaire. "Of regimental tailoring and army cutlery I know nothing. But did not Byron write that immortal line,

"'Ye Stars! which are the poetry of heaven;'

and what think ye did he mean by that? That our sun, with the help of his family, had once since the beginning of things composed an ode; he, after much thought, giving out the first line, his planets with difficulty furnishing a line apiece, the moons attending to the stops, whilst the comets supplied the interjections and notes of admiration. His lordship, too, would intend us to understand, either that copies of this remarkable production were handed round the universe, or that, by a striking coincidence of genius, such as happened more than once to himself and Goethe, each sun with due help composed once in its existence the very same family piece; so that for millions of centuries the stars have all been chanting like the children of an infant school, the same unchanging, meagre version of 'the hand that made us is divine.'

"That might be his lordship's meaning: but might he not, perhaps, intend us to understand something very different, and expect to have our sympathy with another view of things? Our Earth, I think, alone engages to furnish a whole epic of 'Paradise Lost,' through 'Man's first disobedience, and the fruit of that forbidden tree,' and each sphere it is likely has, like Thalaba, its wild and wondrous tale to tell. The poetry of heaven, according to my Lord Byron, or any other of the poet guild, is no solitary sonnet, or single song, but an Olympic contest of Iliads and Odysseys, epics and lyrics, tragedies and comedies, histories in twenty-four books, isolated verses, single hymns, detached odes, and separate songs, where the same poem is never recited twice by one author, nor similar compositions made public by different poets; but in endless diversity, a countless succession of abounding rhymes flows on, of 'grave and gay, and lively and severe,' recounting the history and the destinies of the universe, and glorifying him who sits enthroned as its King."

"Ay! and the Music of the Spheres," will a sweet-tongued juryman say, "is that some unaccompanied melody; some

'Gloria Patri' of three notes; or 'God save the King upon a single string,' played endlessly upon the millions of similar barrel organs that make up the universe? or is the latter some grandest cathedral organ provided not merely with '*vox humana*,' or Earthly stops, but with unnumbered Phœbus flutes, Martial trumpets, Aries horns, Serpent clarions, and pedals touched by the feet of him who walketh on the wings of the wind? Under the vault of heaven it stands a complete orchestra, now with muted voice, as the fingers of God move over one starry bank of keys, lisping under breath some simple melody, then, as they change to another, sounding out a trumpet obligato, or 'when the Highest gives his voice,' rolling forth with open diapason a 'Jupiter symphony,' or guiding the Hallelujah chorus of the morning stars singing together. The starry choir, I ween, is no African row of monotonous performers singing in unison, and able to sing only one song, but a Russian horn-band, where each individual furnishes his indispensable single, and unlike note, towards the universal harmony, and the troop can execute all kinds of music: or a German festival-chorus with its thousand voices, and its unlike parts undulating together into one vast symphony, and flowing on as a mighty river of sound. 'There is no speech or language where their voice is not heard. Their line is gone out through all the earth, and their words to the end of the world.'"

The Chancellor, or Foreman, however, of our twelve, desiring impartiality, and also, as befits his office, loving unity, shall here interpose: "My friends, let not this discerning of diversity prevail with us too far. From the evidence laid before us it should seem, that this solar system of ours is a goodly branch, on the summit of whose stem blooms a brilliant sunflower, whilst round its stalk, at due distances, are arranged the components of its foliage, some twenty broad planet-leaves, and about as many moon-leaflets. Besides these, there are myriads of sharp-pointed, swift-piercing, straggling comet-

thorns, which have occasioned much annoyance to those who have handled them. With these I shall not meddle; but those far distant, non-planetary stars! were it not good to count them sunflowers also, of which on some branches indeed there are two on one stalk, and on others three; larger it may be in certain cases, and fairer than ours, purer in their tints, and varied occasionally in the hue of their petals, but sunflowers all of them, and embosomed in more or fewer leaves and leaflets like those on our own stem? It were no mean and paltry idea of a universe, or meagre scheme of its unity, to compare its clustered stars to unfading flowers blossoming on the branches of one great tree. I should liken it to such a monarch of the wood as Nebuchadnezzar beheld in his night-dream, or better to such as Ezekiel saw in waking vision. 'A cedar in Lebanon with fair branches, and with a shadowing shroud, and of an high stature; and his top was among the thick boughs. . . . . All the fowls of Heaven made their nests in his boughs, and under his branches did all the beasts of the field bring forth their young, and under his shadow dwelt all great nations. . . . . The cedars in the garden of God could not hide him: the fir-trees were not like his boughs, and the chestnut-trees were not like his branches; nor any tree in the garden of God was like unto him in his beauty.'"

"Yes!" one will reply, "that truly were a goodly scheme, and a grand unity, but were it not a better thought, productive of a grander unity, and as likely to be the true one, that that starry universe is no one flowered cedar unvaried in its beauty, but such a tree of life as the Daniel and Ezekiel of the New Testament, the beloved apostle, saw, which bare '*twelve* manner of fruit,' and 'whose leaves were for the healing of the nations?'"

"And were it not," a third will say, "grandest still, and most likely, that that midnight sky shows us no Lebanon with its single cedar, however stately, nor any one tree, however different its flowers, but a whole 'Garden of God,' with its oaks,

and its elms, and its fir-trees; its myrtles and its roses: ay, and its lilies of the valley, its daisies and violets too? Yes! stars are like stars, as flowers are like flowers, but they do not resemble each other as roses do roses, or lilies lilies; but as the rose does the lily, or the dark violet the star-eyed daisy."

Our Chancellor, caught like Absalom in the branches of his own metaphor, shall say no more on the matter in dispute, but content himself with pressing for a conclusion. And thereupon the twelve, various in their unity, shall stand up with uncovered heads in the stillness of night, and lift their unanimous voices to heaven. "By thee only, Judge of all the earth, and all the universe, can this cause be decided, and to the judgment of thy supreme court do we refer it for final issue. But, in the meanwhile, we are free to give our verdict according to the evidence laid before us, and it runs thus:—

"'*There are celestial bodies, and bodies terrestrial: but the glory of the celestial is one, and the glory of the terrestrial is another. There is one glory of the sun, and another glory of the moon, and another glory of the stars: star differeth from star in glory.*'" To which verdict, we, for our part, understanding the words in their widest sense, will append our heartiest Amen.

The "fulness of him that filleth all in all" is of its essence inexhaustible, as we perhaps best realise when all metaphor is set aside, and we reflect on the one quality that belongs to God's attributes: namely, that they are Infinite. It is part of his kindness to us, that he never lets us lose sight of this great prerogative of his nature, but, alike by suns and by atoms, teaches us that his power and his wisdom have no bounds.

It cannot be that he reveals himself otherwise in the oceans of space. Were we privileged to set sail among the shining archipelagoes and starry islands that fill these seas, we should search like marvelling but adoring children for wonder upon wonder, and feel a cold chill of utter disappointment if the

widest diversity did not everywhere prevail. The sense of Unity is an over-ruling power which never lays aside the sceptre, and will not be disobeyed. We should not fear that it would fade away, nay, we know that it would stand forth mightiest when its kingdom seemed to have sunk under overwhelming diversity. Unity is in nature often nearest us exactly when variety seems to have put it furthest away. We are like the sailors of Magellan who first rounded the globe. Every day they sailed further as *they* reckoned from the place of their departure, and ploughed what seemed to *them* a *straight* line of increasing length, which had all to be retraced before their first harbour could be gained: but, behold, when they had sailed longest, and seemed furthest from home, they had the least to sail over, and were nearest to port. Exactly when hope of return was faintest were they called on to exclaim, like the Ancient Mariner—

> "Oh dream of joy! is this indeed
> The lighthouse top I see?
> Is this the hill? is this the kirk?
> Is this my own countree?"

A voyage through space would in like manner turn out to be a circumnavigation. We should set sail from Unity, and traverse the great circle of a universe's variety till we came round to Unity again. The words on our lips as we dropt anchor would be, "There are differences of administrations, but the same Lord, and there are diversities of operations, but it is the same God which worketh all in all."

Our readers may be disposed to think, that in all that has been said we have evasively begged the question. A phantom-jury of men, professedly unlettered, but in reality bearing the same relation to the majority of the different classes they represent, that the pedlar of Wordsworth's "Excursion" does to ordinary pedlars, have disposed of the problem under discussion,

apparently unanimously enough. But if their verdict were submitted to the revision of a tribunal of men of science, it may be thought doubtful whether it would be ratified. Let us transfer, then, the question of the terrestrial or non-terrestrial character of the heavenly bodies, from the "outer court of the gentiles," in which we have hitherto heard it argued, to the "inner court of the priests," even of the high priests of Nature, who serve at her altar, the philosophers properly so called. Our space will not permit us to put on record the judgments of all of them, but we may find room to chronicle the opinions of three of the priestly dignitaries, the Astronomer, the Chemist, and the Physiologist, or Biologist.

A quotation from Sir John Herschel will show the judgment of astronomy on the question we are discussing, so far as the planets are concerned.

"Three features principally strike us as necessarily productive of extraordinary diversity in the provisions by which, if they be, like our earth, inhabited, animal life must be supported. These are, *first*, the difference in their respective supplies of light and heat from the sun; *secondly*, the differences in the intensities of the gravitating forces which must subsist at their surfaces, or the different ratios which on their several globes the *inertiæ* of bodies must bear to their *weights*; and, *thirdly*, *the difference in the nature of the materials of which, from what we know of their mean density, we have every reason to believe they consist*."—*Outlines of Astronomy*, p. 310.

The two first points of diversity noted, refer to differences in the *intensity* of certain influences, which, however, we shall presently find are, of themselves, sufficient to make terrestrial life as we see it, impossible upon at least the majority of the planets. The third is a most explicit reference to a difference in the kind of materials of which the several planets consist, which their difference in density betrays. "The density of Saturn," for example, "hardly exceeds one-eighth of the mean density of the earth, so that it must consist of materials not much heavier than cork."

We shall refer to this question more particularly presently, when discussing the testimony of Chemistry as to the components of the Spheres.

Direct telescopic observation, moreover, has also supplied the astronomer with some information concerning the physical constitution of the heavenly bodies, the chief points of which we condense here, mainly from Herschel's minute descriptions of the characteristic features of each of the members of the solar system.

So far as the sun is concerned, it may suffice our present purpose to say, that nothing certain is known regarding its constitution. It is supposed to have a kind of triple atmosphere, one portion of which is luminous; the second consists of highly reflective clouds, which float below the first, and throw off its light and heat. The third is a mass of gaseous matter, believed to include the luminous and cloudy portions, and to envelope the solid sphere of the sun. In what condition the last is, either as to temperature or to illumination, is quite uncertain; nor is anything known in relation to its composition. Observations, however, on the transit of Venus over the sun's disc, have enabled astronomers to infer that the sun has not an atmosphere of the same nature as that of the Earth; and this may be said to be the only matter tolerably certain concerning solar chemistry. Mercury is too near the sun, Uranus and Neptune too distant from it; Vesta, Ceres, Juno, Pallas, and the other minor planets, too small to permit observations as to the condition of their surfaces. Venus is thought to have an atmosphere, and some have conceived they saw hills on its disc, but the existence of these is doubtful. Mars most resembles the Earth of all the planets. The outlines of what are considered continents are very distinct, and what seem to be seas are equally visible. The polar regions, too, present appearances strongly favouring the idea, that snow or ice is collected at them, thawing in the Martial summer, and becoming more

abundant in its winter. This is by far the most interesting fact, as in truth it is the only positive one, so far as we know, which the telescope has supplied in relation to planetary chemistry. To have good reasons for suspecting that so characteristic and important an earthly ingredient as water occurs in Mars, is assuredly a matter of great interest. The more abundant element of that fluid (oxygen) is also the most important constituent of air, and may perhaps exist free around the planet. A globe which had water, and an oxygen atmosphere, might certainly put in some chemical claim to be a sister of the Earth. But such speculation is premature. The presence of water does not justify the inference that free oxygen is also existent; nor does it warrant the conclusion that more than fifty other elements must be there also. It may further be noticed that the atmosphere of Mars is less distinct and abundant, and much less opaque and cloudy, than we should have expected in the case of a planet thought to possess a great body of water. Astronomers, however, appear to be by no means agreed, either as to the nature or to the extent of the Martial atmosphere. Some deny that there is one at all.

The strange fiery-red light of this star, also, implies a peculiar condition of its whole uncovered surface, very unlike what our Earth's exterior exhibits, and forbids any conclusion as to the general identity of their superficial condition or component ingredients. It still more forbids rash inferences as to terrestrial plants and animals existing on a body of unknown composition.

Nothing is known concerning the surface of Jupiter, which his cloudy atmosphere conceals from inspection; but observations on the eclipses of his moons have shown that that atmosphere does not sensibly refract light. It therefore differs from that of the Earth; but we have at present no means of ascertaining what its constituents are. The disc of Saturn is also

hidden from us by a gaseous or vaporous covering, the nature of which is unknown. His rings are perhaps naked, but they are rarely objects of full telescopic observation, and the state of their surfaces has not been minutely described.

The Earth's satellite is the only moon which has been carefully examined; and we can say more concerning its superficial condition than that of any other of the heavenly bodies. It is the least terrestrial, to appearance, of them all. The moon has no atmosphere, no air, no clouds, no rain, nor dew, nor lakes, nor rivers, nor seas! It has great plains and valleys, but to appearance, barren as the Zahara, for the lunar seasons produce no change on them; nor have traces of vegetable or animal life been detected on any part of its unfruitful surface. It has gigantic mountains, nearly every one an active or extinct volcano, with craters of enormous depth; but their summits and edges relieved from the wearing and disintegrating action of air and water, and unclothed with verdure, are in all cases rugged and sharp, unlike the worn, or covered, and everywhere rounded outlines of our hills. To this astronomical description of the moon we add the remark, that there is something altogether non-terrestrial in the existence of myriads of gigantic volcanic craters, without an atmosphere floating round the sphere containing them, or water existing at its surface; for all the active earthly volcanos pour out volumes of steam and other vapours and gases, which would soon re-clothe our globe with an atmosphere, if it were deprived of its present one.

It does not appear, then, that the telescope favours the idea that a telluric or terrestrial character is common to the members of the solar system. On the other hand, at the sun, the moon, and Jupiter, it brings into view phenomena, which, so far as we can observe them, are so marked and peculiar, as to imply a state of their surfaces quite unlike that of our planet. To the consideration of this we shall return more fully, when referring to the judgment of Biology on the Stars as Theatres

of Life. Meanwhile, we proceed to inquire what decision Chemistry gives on the problem before us. It is to this part of the discussion that we are most anxious to direct the reader's attention, not because it is intrinsically more important than the points already gone over, but because of its comparative novelty, and the erroneous interpretation which has been put upon it.

It might seem, at first sight, as if chemistry could have nothing to say on the matter: yet for ages she has hankered after an alliance with astronomy, and has chronicled the fact in her nomenclature. The alchemist was an astro-chemist, and twin-brother to the astrologer. Gold was Sol; Silver, Luna; Iron, Mars; Lead, Saturn, &c.; and we still speak of lunar caustic, and of martial and saturnine preparations, when referring to certain of the medicinal compounds of silver, iron, and lead. One of the most important of the metals every day reminds us, by its name, Mercury, of the affinity which was once thought to connect it with its namesake, the planet. The astrologist, however, long ago became an astronomer, and the alchemist a chemist; and for a lengthened period they had no dealings together. It has been otherwise latterly. The extension of both sciences has led to their meeting again, and this in a somewhat singular way.

His own little Juan Fernandez island of an earth, was apparently the only spot in the universe of which the chemist could declare, "I am monarch of all I survey." Towards the far distant stars, however, he cast wistful eyes. They were almost all suns, the astronomer told him, which for ages had evolved light and heat, and spread it through space. Can chemistry, then, which for centuries has been explaining—always more and more successfully—the evolution of heat and light on this earth, give no information concerning their production at the sun? It seems that perhaps it may. When a ray of sunlight is passed through a prism, certain "fixed lines" or dark spaces

are seen in the resulting spectrum, unlike those which the spectra of terrestrial flames exhibit. Sirius and Castor, as well as other stars, exhibit peculiar spectra also. "Now a very recent discovery of Sir D. Brewster," as Professor Graham observes, "has given to these observations an entirely chemical character. He has found that the white light of ordinary flames requires merely to be sent through a certain gaseous medium (nitrous acid vapour), to acquire more than a thousand dark lines in its spectrum. He is hence led to infer, that it is the presence of certain gases in the atmosphere of the sun which occasions the observed deficiencies in the solar spectrum. We may thus have it yet in our power to study the nature of the combustion which lights up the suns of other systems."

Such is one example of the way in which chemistry has sought to extend her dominion into space. Another is furnished by the conclusions which Wollaston drew as to the quality of the atmospheres of the Sun and of Jupiter, from the absence in them of power to refract light sensibly, as shown in the case of the Sun, during the transits of Venus, and in that of Jupiter when his moons are eclipsed by him. It has recently, however, been found possible to apply chemical analysis directly to certain of the heavenly bodies, so that, without extravagance, we can now declare that there is a Chemistry of the Stars as well as of the Earth.

The oft-quoted Oriental proverb, which teaches, that since the "mountain will not come to Mahomet, Mahomet must go to the mountain," has in this case, for once, been reversed; for when the chemist could find no way of travelling to the spheres, behold! certain bright particular stars have come to him and submitted to analysis. We refer to the aërolites, meteorites, or meteoric stones, which, according to the most generally adopted of many theories, at one time were thought to have been projected from volcanos in the moon. They are now almost universally acknowledged to have been true stars before they

reached our earth. For a statement of the reasons which have led astronomers to this conclusion, we must refer our readers to Humboldt's "Cosmos," where the whole subject is discussed at great length. It may suffice to say, that many considerations justify the conclusion, that multitudes of asteroids, starlets, or as Sir John Herschel calls them, "meteor-planets," revolve in definite orbits round the sun, and some also as invisible, or momentarily visible, minute moons round the earth. The orbits of some of the former are believed to resemble that of the earth, but to be in a different plane, so that in the course of their revolutions round the sun, these tiny planets come, at certain periods, within the sphere of the earth's attraction, and are precipitated as meteoric stones upon its surface, as weary and forlorn birds of passage, far out at sea, are entangled in the rigging of vessels, and fall helpless on deck.

This modern theory of meteorites reads like a bald rendering of the poetical myth of the angels, whom earthly loves induced to forfeit for ever their places in the heavens, but it has invested the strange fallen stars, to which it refers, with a new interest. The largest of them is but a microscopic grain of the star-dust scattered over the sky, but it is none the less of celestial origin, and may be submitted to analysis.

The meteorites have accordingly been put upon the rack by the chemist, and all their secrets have been tortured out of them, but they have revealed fewer marvels than at one time was expected. No new chemical element or primary ingredient has been found in any of them. In other words, they contain no ultimate chemical component which the earth does not contain. This remarkable fact has seemed to many to justify the belief, that other worlds have been constructed out of the same materials as our own. It is thus, for example, turned to account by the author of the "Vestiges of the Natural History of Creation." After stating that the elements, or simplest chemical constituents of the globe, are those sixty or more

substances which have hitherto resisted all attempts to reduce them to simpler forms of matter, he proceeds thus*: —

"Analogy would lead us to conclude that the modifications of the primordial matter forming our so-called elements, are as universal, or as liable to take place everywhere as are the laws of gravitation and centrifugal force. We must therefore presume that the gases, the metals, the earths, and other simple substances (besides whatever more of which we have no acquaintance), exist, or are liable to come into existence under proper conditions, as well in the Astral system, which is thirty-five thousand times more distant than Sirius, as within the bounds of our own solar system, or our own globe." — *Vestiges*, Fifth Edition, p. 30.

We leave unnoticed, till we proceed with our discussion, the assumption contained in the passage just quoted, that the earth, considered as an aggregate of chemical substances, is a type of the chemistry of the universe. It is thus justified by a reference to the meteoric stones: —

"What is exceedingly remarkable, and particularly worthy of notice as strengthening the argument that all the members of the solar system, and perhaps of other systems, have a similar constitution, no new elements are found in these bodies [meteorites]; *they contain the ordinary materials of the earth*, but associated in a manner altogether new, and unlike anything known in terrestrial mineralogy." — *Vestiges*, Fifth Edition, p. 42.

The clause of this sentence, which we have marked by italics, contrives, by an unwarrantable concealment, to convey a very false impression of the true nature of meteoric stones. They are said to "contain the ordinary materials of the earth," which no doubt they do; but it should have been added, that they contain only *some* of them; so far as we know, but the smaller part.

* The exact number of chemical elements, or simple bodies, is uncertain, as recent researches still incomplete have revealed the existence of several, whose chemical relations have not yet been fully ascertained. We use the integer 60 as sufficiently near the true number for our present purpose.

We have not on record a great number of analyses of meteoric stones, for they are comparatively rare; it would be premature, therefore, to decide that we know all their constituents. But so far as our knowledge extends, it does not appear that a third of our earthly elements has been found in these bodies. Humboldt, in his "Cosmos," quoting from Rammelsberg, the greatest living authority on the subject, enumerates only eighteen of the sixty elements as occurring in them. Professor Shepard counts nineteen as certain, and adds two more as doubtful. It is to be observed, on the other hand, that not only are the majority of the terrestrial elements, including many of the most important among them, totally wanting from meteoric stones, but those which are present are not mingled (as the quotation indeed acknowledges) in earthly proportions.

Our globe consists, speaking generally, of two opposite classes of ingredients,—namely, metals and non-metallic bodies, some of which, as oxygen in the one division, and the precious metals in the other, occur free, but the greater number in combination with some body or bodies of the unlike class. There are many more *kinds* of metals than of non-metallic substances, but the latter, taken as a whole, occur in much larger *quantities* than the former. One non-metallic body alone, oxygen, is computed to form a third of the weight of the crust of the earth. In meteoric stones, on the other hand, whilst non-metallic elements are the less numerous constituents (only a half of those occurring in the earth being found in them), they also occur in much smaller quantities than the metals. Of some of them, indeed, traces only are found.

Many of the best marked aërolites are masses of nearly pure metal, chiefly iron, with a small proportion of nickel. Others contain cobalt, manganese, chromium, copper, and other metals, diffused through them in minute quantities, associated with a small percentage of oxygen, sulphur, chlorine, &c. The stony meteorites consist chiefly of silica and metallic oxides.

Whilst thus, meteoric stones contain only a portion of the elements of the earth, that portion is made up (in the greater number of meteorites), so far as the relative quantities of its components are concerned, almost entirely of metals. A meteoric stone represents, therefore, only a third of the whole constituents of the earth so far as number is concerned, and except to a small extent, but one class of them so far as nature. A globe so constituted could never, by any process of development (unless its so-called elements suffered transmutation), become possessed of water, or an atmosphere, or give birth to terrestrial plants or animals.

It may make the matter clearer to those not minutely conversant with chemistry, who may suspect us of hypercriticism, if we illustrate the force of our argument thus. The conclusion in which we are asked to acquiesce is this strange one, that an aggregate of nineteen, or at the utmost twenty-one ingredients, is the same thing as an aggregate of sixty.* According to this view, a double flageolet of two tubes should be the same thing as a pan-pipe of seven, or an organ with scores of them; and a village fife and drum should be identical with a full military band, because the latter includes a fife and drum. It should thus make no difference whether one inherited an iceberg or a green island, Terra del Fuego or the gold district in California; for the iceberg possesses *to the extent of its possession* (namely, so much ice or solid water), what the fertile island contains, and Terra del Fuego is rich to the extent of its riches in the wealth of California.

Perhaps, however, we are dealing in a misleading exaggeration. The ingredients missing from the meteor-planets may be

* Twenty-one is the aggregate number of chemical elements found in meteoric stones, but no one meteorite contains so many. Some of the best known consist almost entirely of one ingredient. We state the case, therefore, in the way most disadvantageous for our argument when we speak of the meteoric elements as twenty-one in number.

properly enough marked by the minute analyst as absent, and yet be of no great consequence in reference to the suitableness of the latter to become theatres of life. The difference between the meteorite and the earth is perhaps only such as existed between Paganini's fiddle with one string, and Thalberg's piano with some hundred, from both of which instruments the same melody might sound. If such be the case, the author of the "Vestiges" could have no objection to allow us to place him within the receiver of an air-pump, and deprive him of only one of the sixty ingredients,—namely, oxygen—which is absent from many of the meteoric stones. Only twenty-one elements, it should seem, are needed, and we have been kinder to him than he is on paper to himself, for we have allowed him fifty-nine. Why does he pant so? and gasp for breath? Oxygen, it should seem, is no needless superfluity or choice luxury. The lung was not made to breathe without the breath of life being provided for it; and a meteoric stone, as our author before being let out of our receiver shall confess, would be as fatal as a vacuum to every terrestrial creature. Let it be further noticed that the missing elements of the meteoric stone are exactly those which are most abundant in plants and animals, and the worth of our author's reasoning will appear; but to this we shall return.

The chemical argument stripped of all exaggeration, stands thus. Several specimens of the bodies of space have been subjected to analysis,—namely, the earth, so far as its crust or accessible portion is concerned, and meteoric stones. The latter have not a common chemical composition, but are divisible into sections, each of which represents a separate example of planetary chemistry.* When the meteorites and the earth are compared, they are found to differ immensely, so far as the mode of arrangement, the relative quantities, the

* Prof. Shepard divides meteorites into two Classes—*Metallic*, and *Stony*, and each Class into three Orders, under which *thirteen* sections are included.

number and nature of their constituents are concerned. Here, then, are several unlike chemical specimens of the universe. To which among them are the other heavenly bodies to be compared? Analysis has succeeded in making one step beyond this earth, and has immediately brought to light a non-terrestrial chemistry. If it could stride on to sun, moon, and stars, what should it find? Different chemistries? or that of the earth or the meteoric stones endlessly repeated? Different chemistries, we think, and this for many reasons.

If the heavenly bodies were constructed of the terrestrial or the meteoric chemical elements, arranged in the way these are in the earth, or in the meteorites, the densities of the heavenly bodies should, within no very wide limits, be identical with the specific gravity of the earth, or of some one of the meteoric stones; but the opposite is the fact, for the Sun, Jupiter, Saturn, Uranus, and Neptune, have all a density much below that of our planet, or of any of the meteor-planets, as the following table, where the specific gravity of the earth is made unity, will show*:—

Earth, 1; Sun, 0·25; Jupiter, 0·24; Uranus, 0·17; Saturn, 0·14; Neptune, 0·23.

Apart altogether from this difference in density, it is manifest, that confining ourselves to purely chemical considerations, we could assign no satisfactory reason for preferring the earth to the meteoric stones, or the latter to the earth, as types of

* In the table in the text we have not given the sp. gr. of any of the meteorites, because their densities vary so much, that the mean of their specific gravities does not afford a datum of any value in reference to our argument. For the satisfaction, however, of the reader, we may mention that, according to Humboldt, "the specific weight of aërolites varies from 1·9 to 4·3. Their general density may be set down as 3, water being 1." Humboldt's maximum is certainly too low, for various of the American meteorites, examined by Prof. Shepard, have a density above 7; whilst, therefore, the earth is 5·6 times heavier than water, the densest of the meteorites are 7 times heavier, and the lightest within a tenth of being twice as heavy as water.

the chemical composition of one or all of the heavenly bodies; neither can we venture to affirm that we have exhausted in our globe and the meteor-planets the only existing examples of variation in composition which the universe presents, so that every star must be classed with the one or the other, inasmuch as they comprise all the diversities which occur in sidereal chemistry. On the other hand, it is not difficult to show that chemistry amply provides for every star having a different composition, and renders it exceedingly probable that different stars in this respect differ greatly.

In the first place, the chemical elements do not present that character of completeness and unity, considered as a great family, which we should expect in the raw material of a whole universe. When we subdivide them into groups, they arrange themselves unequally. Thus in several cases we find divisions of elements, such as chlorine, bromine, iodine; barium, strontium, calcium; niobium, pelopium, tantalum, in which the characteristic properties of each of the components of the group pass into those of its other members by the most delicate shadings. In other examples, again, although analogous properties are not wanting in related bodies, the particular substance (*ex. gr.*, nitrogen, or mercury) stands apart, isolated as it were, and exhibiting but remote affinities to its nearest neighbours. In all science, however, and strikingly in chemistry, isolation is the exception, and association the rule. In these cases of apparent isolation, it is possible that elements which would make up a group, and connect the solitary in friendly alliance with the families about it, may exist in other worlds, as animals supplying gaps in the zoological circles are found extinct in the strata of other eras than our own. Such hypothetically deficient elements no doubt may yet be found in our own globe, but for the present, we must adopt the rule, "de non apparentibus, et de non existentibus, eadem ratio." Or we may find all the so-called elements to be modifications

of some simpler or simplest forms or form of matter, and be able to convert that into unknown substances of the same grade as our present elements, and so satisfy the supposed need of harmony. Even if we should, however, achieve this result, it would only alter the mode of stating the problem, which would then run thus,—What forms of the primary matter are likely to occur in different globes?

Secondly, it may be remarked that some of our terrestrial elements, such as the metals of the earths proper (except aluminum) and also selenium, tellurium, molybden, vanadium, tungsten, as well as others, are not known to be of service in our globe. It would be very rash to permit our ignorance to be the measure of a question like this. These bodies may have been, or may yet be, even if they are not at present, (which, however, is only an assumption,) of the utmost value in effecting necessary changes on the earth. Man, too, as his knowledge extends, may discover economical applications of the elements in question of the greatest importance. Withal, however, we may suppose that some, at least, of these substances may not have been specially destined to be of use on our globe, but may bear the same relation to it that rudimentary organs do to the bodies of the animals possessing them, so that they are of little or no service to the structure in which they occur, but are typical of much more highly developed instruments, or arrangements, in other organisms or spheres. These seemingly useless, and sparingly distributed bodies in our earth, may be the prevailing or most important constituents of other globes, and may perform functions there of which we have no conception. Other elements, such as arsenic, yield compounds so deadly to vegetable and animal life, and so apparently unserviceable in the mineral kingdom, that one is almost driven to believe that it was not primarily for us, but for some other beings in a different world, such bodies were provided. At least, we suppose there are few who will consider the slight service which arsenical

preparations have rendered to medicine, or their efficacy in poisoning rats and flies, and the fact of their furnishing certain pigments, as an equivalent for the multitude of human beings whom they have consigned to untimely graves, and the many crimes to which they have furnished temptations.

Thirdly, nature has been very niggard to us of certain of the elements, for example, of one peculiar and very valuable class, the noble or precious metals, gold, platina, palladium, rhodium, &c. We do not refer to the scarcity of these as limiting our luxury, or count them precious in the sense of being costly. Gold and platina, to mention no others, have the desirable properties of never wasting, rusting, or corroding, and platina will not melt in the heat of a blast-furnace. Were these or the allied metals more abundant, our eating, drinking, and cooking vessels would be made of one or other of them. Our steam-boilers, railroads, furnace-bars, lamp-posts, and the like, would be constructed of platina, rhodium, or palladium, and our lighter and more elegant instruments and utensils of gold, which would be too cheap to tempt thieves to steal. One may suppose that other worlds may have been more richly favoured than we are with supplies of these or other goodly bodies, which find so limited scope for exhibiting their manifold virtues here. Can platina, *ex. gr.*, considered as a veritable, simple substance, be supposed to have been created solely to supply the terrestrial chemist with tests and crucibles? The chemist will probably think that a very satisfactory final cause for its creation, and we will not cry nay to it. But what if there be worlds where this metal is so abundant that they are sick of the sight of it, and would be glad to see a piece of rusty old iron, where the thieves steal the costly magnesia, and the royal crowns are made of the precious metal, lead? To speak more soberly, is it very unlikely that so marked and striking a metal as platina, as well as its congeners, may occur more abundantly in other worlds framed on a different ideal from

ours? We have no wish, however, to try our hand at improving God's fair and beautiful world.

To sum up the matter, we observe, without insisting on more, that we have no ground for assuming that we see on this earth all the kinds of elementary, or quasi-elementary matter which can exist. Still less are we justified in affirming that we have manifested on this globe the only modes of arrangement or of distribution, so far as relative quantity is concerned, of which our elements are susceptible. The very opposite is likely to be the case. The fact of their being *many* chemical elements awakens the suspicion that they were intended to be arranged in *many* ways. Had our globe been a ball of iron, or of lead, we should have had nothing to suspect in space but iron or lead. But when there are more than sixty earthly constituents, arranged, too, in a quite arbitrary way, we cannot resist the expectation that they will be found apportioned among the celestial spheres, not in that one way, but in various ways: here a few, there many together; in one globe, bodies of one class; in another, of another; in no one, perhaps, exactly the arrangement that prevails in any of the rest. Our globe may be called a mosaic of some sixty pieces, but it has not pleased the Great Artist to make equal use of each of the sixty. Not more than a half of them can be detected except by minute inspection, and the predominating tints are only some six or seven. Other stars may be mosaics constructed out of more or fewer of the same pieces, but they are, in all probability, put together according to different patterns. Let it not be forgotten that the omission of a single element would make a great difference. A globe in all other respects identical with ours would be utterly unfitted for being the theatre of life such as we see, if it wanted, as we have already noticed, but the one body oxygen, or hydrogen, or nitrogen, or carbon. The addition in considerable quantity of a single new potent element would equally derange the economy of a world. The arrangement in

a different way, without addition or abstraction, of existing elements would be as efficacious a cause of disturbance. If, for example, the nitrogen and oxygen of our atmosphere were suddenly to combine (and every thunderstorm occasions combination), we might be maddened by laughing-gas, or drowned in an ocean of nitric acid. The shades of variation in such a case would become shadows of most portentous depth and darkness.

If any one, indeed, will consider how many tunes can be made with the seven primary notes of music; how many numbers can be combined out of the ten numerals; how many words out of the twenty-four letters of the alphabet, he may conceive how enormously great is the number of worlds, each quite distinct, which could be constructed out of the sixty elements. In the first place, there is a means of variety in the *number* of the simple bodies. One globe, like our earth, contains them all. Others, like the meteoric stones, may contain only some of them. Secondly, the *relative quantities* of the elements may vary. On one globe, the abounding element may be oxygen, as in our earth; in another, platina. A third cause of variety will be the *condition* of the elements. With us, hundreds of tons of chlorine are locked up in mountains of rock salt. In other worlds, that gas may be free, and form an atmosphere like our air.

Add these modes of varying composition together, and employ them all, and where will the variety stop? Millions of millions of worlds would not exhaust it. To what extent this susceptibility of variation has been taken advantage of by the Architect of the Heavens we cannot tell; but to suppose that it has been turned to no account seems a conception meagre beyond endurance. If we but knew the use to which the spheres are put, we might possibly hazard a conjecture concerning their composition, but of that we are altogether ignorant. Yet to suppose that the Infinite One has exhausted

the counsels of his wisdom in arranging the chemistry of our globe, and could only therefore repeat that endlessly through space, or to affirm that such a monotonous arrangement of the great world or universe is in keeping with the endless diversity visible in the little one which we inhabit, is a view of things that may not be entertained for a moment.

We close this long chemical discussion with one remark. Speculation set aside, the testimony of chemistry in reference to the heavenly bodies is neither more nor less than this, that every one of them which has been submitted to analysis, differs in composition from all the rest. Absolute chemical identity of any two or more has never been observed, whilst the extremes of difference between those least like each other, if denoted on a scale, would be 60 and 1; the maximum of this scale being the earth with its sixty ingredients, the minimum, those well known meteorites, which are little else than lumps of malleable iron. The importance of this fact has been overlooked, because, beginning with the earth, we have found the meteor-planets composed of fewer ingredients than it, and these all terrestrial.

Assuredly it would have been a more remarkable circumstance, if the meteoric elements had all been novel, and possessed of striking and unfamiliar properties; and something like disappointment has been felt because they are not. But we must not on this account disregard the fact that the meteorites are non-telluric in their chemical characters. They are so, as much by the terrestrial elements they want, as they would have been by the novel elements they might have possessed. Had a single non-terrestrial element been found in a meteoric stone, our philosophers would have been lost in wonder. Yet within the last ten years, six or seven new elements, namely, Didymium, Lanthanum, Niobium, Pelopium, Tantalum, Erbium, Terbium, have been discovered in our own planet, and none but professed chemists have paid any attention to the

fact, nor has the discovery perceptibly altered any of our scientific beliefs. Had but one of those obscure metals been found in a meteorite, and in it alone, speculations would have abounded on its nature and uses. Nevertheless, the addition of six or seven such metals to our globe, by the tacit confession of all science, is of infinitely less importance to the earth, than the loss of one such element as oxygen, hydrogen, nitrogen, or carbon would be. To find, therefore, one of the latter absent, is truly a more interesting fact in relation to terrestrial chemistry, than it would be to find *all* of the recently discovered metals, or as many more similar elements, present. The most richly endowed of the meteoric stones, moreover, contain not a majority, but less than a fourth of the terrestrial elements, and of many of the most characteristically terrestrial elements, only traces. As soon as this fact is distinctly perceived, men will cease to complain that there are no new meteoric elements, and none will refuse to acknowledge that so far as analysis has proceeded, terrestrial and sidereal chemistry are quite different.

It remains now only to consider what the judgment of physiology or biology is likely to be concerning the manifestation of life in the heavenly bodies. It has to a considerable extent been anticipated or implied, in what has been stated already.

Life, as it exists on this globe, is compatible only with certain conditions, which may not be overstepped without causing its annihilation. The whole of these need not be enumerated, as the failure of one is as fatal to existence, as the absence of all. The three to which Sir John Herschel has referred, namely, difference in the quantity of heat and light reaching each globe; variation in the intensity of gravity at its surface; and in the quality of its component materials, may suffice to illustrate this. Light and heat are essential to the development and maintenance of earthly life, but their excess is as destructive to it as their deficiency. What, then, shall we say of the sun, whose

heat we know by direct trial to be of such intensity, that after great degradation or reduction, it can still melt the most infusible minerals, and dissipate every metal in vapour; and whose light is so intolerably brilliant, "that the most vivid flames disappear, and the most intensely ignited solids appear only as black spots on the disc of the sun, when held between it and the eye?" If the temperature of the solid sphere or body of the sun be such as those phenomena imply, it must be the abode, if inhabited at all, of beings such as Sir Thomas Browne refers to, who can "lie immortal in the arms of fire." It is within possibility, however, that the body of the sun, is black as midnight and cold as death, so that as the eye sees all things but itself, he illuminates every sphere but his own, and is light to other stars, but darkness to his own gaze. Or the light and heat of his blazing envelope may be so tempered by the reflective clouds of his atmosphere, which throw them off into space, that an endless summer, a nightless summer-day, reigns on his globe. Such an unbroken summer, however, though pleasant to dream of, would be no boon to terrestrial creatures, to whom night is as essential as day, and darkness and rest as light and action. The probabilities are all in favour of the temperature of the sun's solid sphere being very high, nor will any reasonable hypothesis justify the belief that the economy of his system in relation to the distribution of light and heat can resemble ours.

We can assert this still more distinctly of the planets. We should be blinded with the glare and burnt up if transported to Mercury, where the sun acts as if seven times hotter than on this earth; and we should shiver in the dark, and be frozen to death if removed to Uranus, where the sun is three hundred times colder than he is felt to be by us. To pass from Uranus to Mercury, would be to undergo in the latter exposure to a temperature some two thousand times higher than we had experienced in the former, whilst on this earth the range of

existence lies within some two hundred degrees of the Fahrenheit thermometer.

As for our satellite, Sir John Herschel says of it, "The climate of the moon must be very extraordinary: the alternation being that of unmitigated and burning sunshine, fiercer than an equatorial noon, continued for a whole fortnight, and the keenest severity of frost, far exceeding that of our polar winters, for an equal time." It would seem, then, that though all else were equal, the variations in amount of light and heat, would alone necessitate the manifestation of a non-terrestrial life upon the sun, and the spheres which accompany the earth in its revolutions around it. All else, however, is not equal. The intensity of gravity at the surfaces of the different heavenly bodies differs enormously. At the sun it is nearly twenty-eight times greater than at the earth. "The efficacy of muscular power to overcome weight is therefore proportionably nearly twenty-eight times less on the sun than on the earth. An ordinary man, for example, would not only be unable to sustain his own weight on the sun, but would literally be crushed to atoms under the load." "Again, the intensity of gravity, or its efficacy in counteracting muscular power, and repressing animal activity on Jupiter, is nearly two and a half times that on the earth, on Mars is not more than one-half, on the moon one-sixth, and on the smaller planets probably not more than one-twentieth; giving a scale of which the extremes are in the proportion of sixty to one."

From this account it appears that we should be literally mercurial in Mercury, saturnine in Saturn, and anything but jovial in Jupiter, where we should be two and a half times heavier and duller than here. On the smaller planets we should feel like swimmers in the Dead Sea, or as if in a bath of quicksilver, where to sink is impossible. "A man placed on one of them would spring with ease sixty feet high, and sustain no greater shock in his descent than he does on the

earth from leaping a yard. On such planets giants might exist, and those enormous animals which on earth require the buoyant power of water to counteract their weight, might there be denizens of the land." If the fixed stars be suns, of what ponderous adamant must the beings be fashioned which exist on their surfaces! Were it possible for us, clothed in some frigorific asbestos garment, to endure unscathed the flames of Sirius, it would only be to be crushed to powder against his enormous globe. Here, then, is a second point of diversity, of itself sufficient to forbid the development of the earth-life we see here on almost any other of the heavenly bodies.

And we do not require to enlarge upon the third point of diversity—variation in the chemical composition of the spheres. The absence of an atmosphere from the moon, and the peculiar characters of that of Jupiter and of the sun, have already been referred to as forbidding the appearance of terrestrial life under their skies. The impossibility of its manifestation on meteor-planets such as have reached our earth has also been sufficiently dwelt upon.

In the face of the immense diversity which has thus been shown to prevail through space, it should seem impossible to hold the belief that the stars are all but so many Earths. The author of the "Vestiges," however, in his blind zeal for the nebular hypothesis of a common physical origin of all worlds, and solicitous to save God the trouble of taking care of his own universe, thinks otherwise.

"We *see*," says he, speaking as if the nebular hypothesis were an established fact, "that matter has originally been diffused in one mass, of which the spheres are portions. Consequently, *inorganic matter must be presumed to be everywhere the same*, although probably with differences in the proportions of ingredients in different globes, and also some difference of conditions. Out of a certain number of the elements of inorganic matter are composed the elements of organic bodies, both

vegetable and animal, *such must be the rule* in Jupiter and in Sirius as it is here. We are, therefore, *all but certain* that herbaceous and ligneous fibre, that flesh and blood, are the constituents of the organic beings of all those spheres which are as yet seats of life." (p. 171.)

He proceeds a little further on to say, "Where there is light, there will be eyes; and these, in other spheres, will be the same in all respects as the eyes of tellurian animals, with only such differences as may be necessary to accord with minor peculiarities of condition and of situation. It is," he adds, "but a small stretch of the argument to suppose that one conspicuous organ of a large portion of our animal kingdom being thus universal, a parity in all the other organs,—species for species, class for class, kingdom for kingdom,—is highly likely, and that thus the inhabitants of all the other globes of space have not only a general but a particular resemblance to those of our own." (p. 172.) How baseless this reasoning is, with its "small stretch" at the close, we need not stop to demonstrate anew, but a few words may be added, in reference to the concluding argument concerning the relation of eyes to light.

It is a hasty and unwarrantable conclusion that every illuminated globe must contain living eyes. On our own earth there are many animals without organs of vision; so that we cannot conclude that eyes are a necessary reaction of light and life upon each other. Worlds may be supplied with light for other reasons than to endow their inhabitants with the faculty of sight. Our sun is a centre of many influences. We know at least three which may be separated from each other—light, heat, and what has been called actinic or chemical force; but probably electricity and magnetism also emanate from his orb. Terrestrial plants and animals are powerfully affected by most, probably by all of those; but the inhabitants of other spheres

may not have organs enabling them to take advantage of more than some, perhaps only of one of the forces in question. On the other hand, the sun may be the source of agencies of which we know nothing, which are about us and yet do not affect us, because we have no channels or senses by which they can find access to us. The dwellers in other planets may have organs of which we have no conception, enabling them to enjoy these either as substitutes for the influences which affect us, or in addition to them.

Our sun, it is true, sends light to his several planets and their moons, but that they all make the same use of it is in no degree probable. They may, some of them at least, be "old in rayless blindness," yet not like Schiller's Proserpine, "aching for the gold-bright light in vain." They may have "knowledge at one entrance quite shut out;" but so likely enough have we, and at more entrances, perhaps, than one. The sun may impartially distribute the same gifts, though in unequal quantities to his family; but it depends on each member of the circle what improvement is made of them. Mercury, who receives Benjamin's portion, may well be expected to show a different result from the newly-discovered, scantily-endowed Neptune, who has so long and so mysteriously tempted Uranus from his course. We would liken the different planets and satellites of our system to so many pieces of stained glass in a cathedral window; on every one, the same seven-tinted light falls, but the chemical composition, and molecular arrangement of each transparent sheet determines whether it turns to account the whole seven and gleams white, or profits only by certain of them, and shows, in consequence, green or red, blue, purple, or yellow. If some tiny fly, whose dominion was limited to the inside of a single pane, should suppose that, as its kingdom was bathed in unchanging red, every other sheet of glass must be "vermeil tinctured" also, because it knew that on every one

the same light fell, it would greatly err, as we are wise enough to know. But we who are "crushed before the moth," probably err as widely, if we affirm that each of the planets is a mirror reflecting the sun in the same way. He is probably like a fountain, sending forth a river charged with many dissimilar substances, and each of the planets resembles a filter, separating from the stream what its construction enables it to retain, and what was intended and is fitted to be appropriated by it.

Even, however, if we should concede to our author that wherever there is light there will be eyes, surely a few more data are necessary, before a whole animal can be assumed. Can we infer that lungs or other breathing-organs exist, unless we make it probable that there is an atmosphere to breathe? Can we take for granted wings of birds or of insects, unless we show that there is air to fan? or, may we count on the "hearing ear" before we establish that there is a gaseous or aqueous medium to transmit the undulations of sound? If there be no water, will there be paddles of whales or of turtles, or fins of fishes? If no carbon, will there be leaf or stem of flower or tree? If no lime, bone or skeleton of any animal? The existence of all these organs cannot be assumed merely because there is light. But, in truth, as little can organs of vision. For if there be no water, there can be no blood; and if no blood, then not even eyes, at least earthly eyes, however constant and brilliant the light may be.

The unequivocal testimony, then, of physical science, as it seems to us, is against the doctrine that life, as it appears on the stars, must be terrestrial in its nature, though we are far from wishing to affirm that planets closely resembling the earth may not occur in space. It is enough for our argument to show that there are myriads of stars, which, for the reasons already given, are altogether non-terrestrial in their characters.

It remains, then, to inquire, whether we are to come to the conclusion, that the stars are uninhabited, inasmuch as terrestrial life is the only possible one, or to believe that there exists a diversified astral life which is manifested on them. Abstaining from anything like an attempt to define positively the probable characteristics of the latter, if it exists, we may say this much on the matter. There are fewer characters of universality in terrestrial life than in terrestrial chemistry. There is a plant-life and an animal-life, which are quite separable, and may exist apart, and there are different kinds of each. To mention but one example: the egg of the butterfly has one life, and the caterpillar which springs from it has another; and the chrysalis into which the caterpillar changes has a third, and the butterfly which rises from the chrysalis has a fourth; and so there may be worlds which know only a germinal, or a caterpillar, a chrysalis, or a butterfly life.

Further, in this world we see plants and the lowest animals possessing only the sense of touch, if the former can be said to be endowed even with that. Gradually as we ascend in the animal scale, additional senses are manifested, till four more appear in the highest animals. But who shall tell us that these five are the only possible, or even the only existing channels of communication with the outer world? We might, besides the general argument from analogy against such a conception, refer to those agencies influencing living beings, which have been recognised for centuries as implying some supersensuous relation to external nature. It would be unwise to allow the extravagances of animal magnetism to prevent us from recognising the indications which several of its phenomena afford, of perceptions of outward things not easily referable to the operation of any of the known senses. Nevertheless, that so-called, and as yet questionable science, has, for a season at least, fallen into the hands of those with whom the gratification

of wonder is a much greater object than the discovery of truth and we fear to build much upon it. We can find, in another and quite unexceptionable quarter, a substantial foundation on which to assert the probability of life being manifested very differently in other spheres than it is in our own globe. We refer to the assurance which the New Testament gives us, that our human spirits are destined to occupy bodies altogether unlike our present ones.

From the remarkable way in which the Apostle Paul likens the "natural body" to a seed which is to be sown, and grow up a "spiritual body," one is led to believe that the immortal future tabernacle is to bear the same relation of difference, and yet of derivation to the present mortal one which a tree does to a seed. The one will be as unlike the other as the oak is unlike the acorn, though but in a sense the expansion of it.

Whether this be the doctrine or not which the Apostle teaches, it is at least certain, that he announces that a great and inconceivable alteration is to come over our bodies. Doubtless, our spirits are to be changed also, but more, as it seems, in the way of intensification of faculties, desires, passions, and affections—on the one hand, good, on the other, evil—which have been exercised or experienced, in their fainter manifestations, in the present state of existence, than by the introduction of positively new elements into our intellectual and moral being. We do not urge this point; it is enough if it be acknowledged to be a Scripture doctrine, that human spirits, reminiscent of their past history, and conscious of their identity, are, however otherwise changed, to occupy bodies totally unlike our present ones. If, however, it be supposed that the "spiritual" occupants of our future tabernacles are to differ totally from us, it only adds to the force of the argument, as it implies the greater diversity as to the manner in which being may manifest

itself. It is part, then, of the scheme of God's universe, that spirits clothed in non-earthly bodies shall dwell in it. It is idle, therefore, to say that terrestrial life is certainly the probable sidereal one, since it is not the only existing, or at least the only contemplated mode of being. In looking at the stars as habitations of living creatures, we have at least two unlike examples of the way in which mind and matter admit of association to choose from, as patterns of what astral life may be. But the further lesson is surely taught us, that there may exist other manifestations of life than only these two. For the spell of simplicity once broken by a single variation, we know not how many more to expect, whilst the conclusion is not to be resisted, that other variations there will be. The same Apostle who dwells on the resurrection, tells us, in reference to the happy dead, that eye "hath not seen, nor ear heard, neither have entered into the heart of man, the things which God hath prepared for them that love him." They are not only, therefore, to have bodily organs different from ours, but these are to be gratified by sights which our eyes have not witnessed, by sounds to which our ears have never listened, and by a perception of phenomena inconceivable by us. There are here indicated the two great elements of variety to which we have already referred; a theatre of existence totally unlike the present one, and organs of relation to it different from those of terrestrial beings.

The argument might be greatly extended, but we cannot attempt here an exhaustive discussion of the subject. The sum of the whole inquiry is this:—Astronomy declares that there are unlike theatres of existence in the heavens,—suns, moons, and planets; Chemistry demonstrates that different kinds of construction, that of the earth, and those of the meteoric stones, prevail through space; Physiology contemplates the possibility of a non-terrestrial life unfolding itself in

the stars; and the Bible reveals to us, that there is an immortal heavenly, as well as a mortal earthly life.

The consideration of all this leaves no place for the thought, that the tide of life which ebbs and flows through the universe is but the undulation of so many streamlets identical with that which bathes the shores of our globe. In our Father's house are many mansions, and the Great Shepherd watches over countless flocks, and has other sheep which are not of this fold.

THE END.

LONDON:
PRINTED BY SPOTTISWOODE AND CO.
NEW-STREET SQUARE.

NEW EDITION OF CONYBEARE AND HOWSON'S "ST. PAUL."

Just published, in 2 vols. square crown 8vo. with numerous Maps and Woodcuts, and Four Plates, price 31s. 6d. cloth,

THE LIFE AND EPISTLES OF ST. PAUL.

BY

THE REV. W. J. CONYBEARE, M.A.